NASA TM X-73967

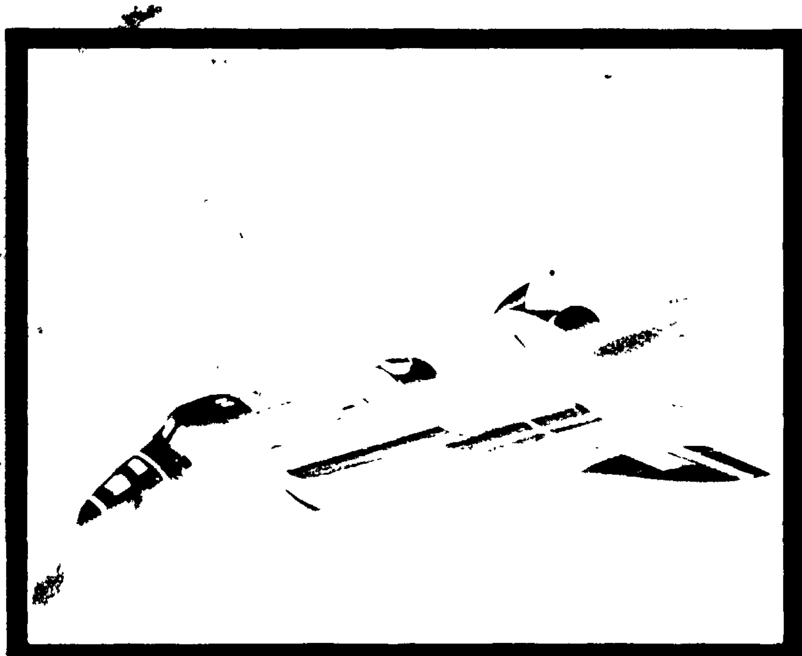
(NASA-TM-X-73967) NASA OFFICE OF AERONAUTICAL AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 7: MATERIALS PANEL Final Report (NASA) 170 p HC A08/MF A01 CSCL 11G

N77-13916

Unclas

G3/65 56957

MATERIALS



OAST Summer Workshop

NASA GRANT
NSG 1186

OAST | ODU

1975

National Aeronautics
and Space Administration
Office of Aeronautics and Space
Technology and Old Dominion University

OLD DOMINION UNIVERSITY 1930

Vol. VII of XI

NOTICE

The results of the OAST Space Technology Workshop which was held at Madison College, Harrisonburg, Virginia, August 3 - 15, 1975 are contained in the following reports:

Copies of these reports may be obtained by contacting:

NASA - LANGLEY RESEARCH CENTER

ATTN: 418/CHARLES I. TYNAN, JR.

HAMPTON, VA. 23665

COMMERCIAL TELEPHONE: 804/827-3666

FEDERAL TELECOMMUNICATIONS SYSTEM: 928-3666

N A S A

Office of Aeronautics and Space Technology

Summer Workshop

August 3 through 16, 1975

Conducted at Madison College, Harrisonburg, Virginia

Final Report

MATERIALS PANEL

Volume VII of XI

OAST Space Technology Workshop

MATERIALS TECHNOLOGY PANEL

Robert A. Signorelli
CHAIRMAN
LEWIS RESEARCH CENTER

MEMBERS:

J. J. GANGLER .... OAST
W. D. KLOPP .... LEWIS RESEARCH CENTER
R. LAD .... LEWIS RESEARCH CENTER
W. B. LISAGOR .... LANGLEY RESEARCH CENTER
E. C. McKANNON .... OAST
H. G. NELSON .... AMES RESEARCH CENTER
C. H. SAVAGE .... JET PROPULSION LABORATORY
C. E. VEST .... GODDARD SPACE FLIGHT CENTER

COLLABORATOR:

STEPHEN G. CUPSCHALK
ASSOCIATE PROFESSOR
MECHANICAL ENGINEERING
& MECHANICS
OLD DOMINION UNIVERSITY

The Materials area is defined by this workshop in that which is pertinent to mission and flight experiment requirements for Structures, Power, and Propulsion. Technology and flight experiment needs in other areas such as Thermal Control, Electronic, Entry Technology, and Life Support are included in those sections.

MISSION DRIVEN MATERIALS TECHNOLOGY

Most Materials Technology Requirements have been classified as mission-driven because, from a materials viewpoint, a mission demand can be defined in every case, even for those cases for which the applications technology does not recognize the benefits. It is obvious that a large majority of applications devolve into materials problems. An equivalent statement may be that an important function of the materials community is to define that the limits of performance of materials: these limitations are based, at any particular time, on the properties of the materials of interest and a knowledge of development potential both in properties and other factors such as cost and availability. Alternate materials and their potential improvements are also a factor.

The Materials Technology Requirements have been classified in two ways. First the separation has been according to materials class, namely, Metals, Ceramics, Polymers, and Composites. The polymer classification also includes organic compounds research and development in areas such as lubricants and organic superconductors. The second grouping, within each of the above classifications, consists of Development, Characterization, Manufacturing, and Basic Research. The compilation of Technology Requirements in this section is in accord with the above classification. Each requirement is further identified with respect to applications to Structures, Power, and Propulsion as well as to other pertinent areas.

Development is defined, for the purpose of this report, as the improvement of known materials and the synthesis of new materials using known phenomena and techniques. Characterization is the accumulation of property and environmental data necessary to predict whether a developed, available material will fulfill a certain mission requirement and whether it can be used with confidence by designers. Manufacturing refers to the process techniques which are required to produce a material in a form which is useful in a mission.

Topics in the Basic Research area resulted from considerations of two kinds. One was the recognizable needs for basic understanding that stem from the developments and applications that are foreseen for particular materials, e.g., composites and catalysts. The second consideration was the recognizable needs for advancement of understanding in the various areas of solid state physics, physical chemistry and others that directly pertain to materials development and applications. Examples are diffusion in alloys and the physics and chemistry of surfaces.

OPPORTUNITY DRIVEN MATERIALS TECHNOLOGY

Space processing of materials has been taken to be opportunity driven. It is designed to satisfy one of several requirements:

1.) To supply data unobtainable on the ground.

2.) To run demonstrations for design purposes.

3.) To manufacture materials under conditions unobtainable on the ground.

4.) To manufacture or process materials in space for space use (possibly in the future from new materials obtained in space).

The ability to operate effectively in the low gravity environment of near earth orbit has provided a unique opportunity to do new materials research. The low gravity aspect of the environment, in particular, has excited interest in a host of new materials possibilities such as: containerless solidification and handling (levitation) for materials whose development on earth have been limited by reaction with containers, dies, and molds; reduced convection in liquids leading to better control of the solidifying interface; and mixing of otherwise immiscible materials because of the elimination of density driven stratification. Research in the low gravity environment will lead to a better understanding of basic materials phenomena which are currently thought to limit earthbound processing. It will also lead to manufacturing in space where the economic trade-off with transportation and energy requirements permit.

CONTENT OF THE BODY OF THE MATERIALS WORKING GROUP PORTION OF THE REPORT

The space Materials Technology Requirements identified by the working group are attached. These have been divided into several categories. A narrative description was proposed on all items identified. A total of 52 items were included broken into Mission Driven (48 requirements) and Opportunity Driven (4 requirements). In addition, those items for which a flight experiment was proposed were included again. A total of 27 candidate flight experiments were proposed.

The need to index the topics was addressed as follows. A list of the titles of each narrative is attached. Further, a number has been assigned to each narrative and index and cross index have been prepared on the basis of a discipline matrix and of a discipline/application matrix.

Studies on materials processing in space have been going on for several years. This work has been supported by the Office of Applications in NASA, but much of the emphasis has been on capitalizing on current flight opportunities and rapid pay-off. These flight experiments have indicated that more extensive ground based preparations and several iterative flight and ground experiments are needed to understand the problems involved in order to achieve the expected results. At this juncture, OAST needs to become involved in planning and directing the longer range development program on a larger scale.

Materials processing in space is divided into three areas: (a) development of commercially desired products needed in the industrial market (such as improved semi-conductors), (b) exploitation of the environment in performing basic research to improve the understanding of materials phenomena (such as solidification) which have a more distant pay-off, and (c) manufacturing and assembly in space to support missions such as solar energy stations which require the forming, erection, joining, and repair of structures in space. Area A will continue to be supported by the Office of Applications. Tasks in areas B and C are proposed in the following document.

LIST OF

SPACE MATERIALS TECHNOLOGY REQUIREMENTS

Mission Driven

1. Materials with High Thermal Conductivity and High Strength at High Temperatures for Rocket Motor Nozzles

2. Higher Temperature Superconducting Materials

3. Lunar Extractive Metallurgy

4. Environmental Interactions - Meteoroids and Radiation

5. Development and Characterization of Refractory Metals For Space Power Systems

6. Fracture Toughness/Strength Optimization of High Strength Structural Alloy Systems

7. Utilization of Magnesium, Beryllium, and Beryllium-Aluminum Alloys in Advanced Space Structures

8. Low Cycle Thermal Fatigue of Superalloys

9. Fatigue, Fracture and Life Prediction of Metallic Structures Exposed to Chemical Environments

10. NDT/NDE - Earth and Space

11. Development of Elastic-Plastic Failure Criteria

12. Solar Cell Solder Connections with Extended Life During Thermal Cycling in Orbit

13. Joining Metals in Space

14. Basic Studies of Electromigration in Metals and Alloys

15. Theoretical Studies of Diffusion in Alloys

16. Basic Studies in Catalysis

17. Basic Studies of Mechanisms of Hydrogen Embrittlement

18. Basic Studies of New Concepts for Solar Cells

19. Solid State Diffusion Studies in Space

20. Experimental Studies of Diffusion in Alloys

21. Phase Diagram Studies in Space

22. Measurement of Vapor Pressure of Corrosive Materials

23. Basic Studies of Gas-Surface Reactions

24. High Temperature Insulations

25. Structural Ceramics

26. Ceramic Fibers for Composites

27. Large Area Polymer Films for Space Applications

28. Adhesive Bonding of Large, Erectable Structures in Space

29. Long Life Polymeric Protective Coatings for Space Applications

30. Long Life Adhesives for Space Applications

31. High Temperature, High Thermal Conductivity Polymeric Materials

32. Improved Electrical Conductivity Polymeric Materials

33. Retention of Liquid Lubricants by Passive Means Under Passive Conditions

34. Retention of Liquid Lubricants "in Place' Under Dynamic Conditions

35. Effects of the Space Environment on the Properties of Specific Polymeric Materials

36. Space Repair of Polymers in Electronic Assemblies

37. Basic Studies of the Relation Between Molecular Structure and Mechanical Behavior of Polymers

38. Basic Studies of Polymer Matrix Composite Structure Behavior

39. Basic Studies in Electrochemistry

40. Physics and Chemistry of Organic Superconductors

41. Low Thermal Expansion Composite Materials for Space Structures

42. Standardization of Composite Materials Processing and Testing

43. Effect of Long Duration Space Exposure on Properties of Composite Materials

44. Characterization of Damage Mechanisms Associated with Failure and Degradation of Composite Materials

45. Manufacturing of Composite Materials in Space

46. Materials and Processes for Assembly of Structures in Space

47. Basic Solid State Physics of Metal Matrix Composites

48. Studies of Creep and Fracture Mechanisms in Composites

Sub Total 48

Opportunity Driven

49. Development of Directionally Solidified Eutectic Compounds in Space

50. Containerless Casting and Shaping of Reactive Metals in Space

51. Fabrication, Assembly, and Joining of Materials for Large Space Structures

52. Space Processing of Ceramics and Glass

Sub Total 4

LIST OF

CANDIDATE FLIGHT EXPERIMENTS

5a Refractory Metal Heat pipes

5b Refractory Metal Contamination

7 Light Metal Alloys - Long Time, Low Earth Orbit Exposure on Mechanical Stability

9a Processing and Use of Chemically-Active Metals in Space and Planetary Environments

9b Solid-Solid Metal Embrittlement in the Space Environment

10 NDT/NDE - Earth and Space

11 Influence of Long Term Space Exposure on Localized Plasticity in Metals

12 Solar Cell Solder Connections with Extended Life During Thermal Cycling in Orbit

13 Joining Metals in Space

19 Solid State Diffusion Studies

21 Phase Diagram Studies at Low Pressure and Zero g

22 High Temperature Vaporization Studies of Corrosive Molten Salts

28 Adhesive Bonding of Large Erectable

29 Long Life Polymeric Protective Coatings for Space Applications

30 Long Life Adhesives for Space Applications

31 High Temperature High Thermal Conductivity of Polymers for Space Application

32 Improved Electrical Conductivity of Polymers for Space Application

33 Retention of Liquid Lubricants by Passive Means in Space Environment Under Passive Conditions

34 Retention of Liquid Lubricants "in Place" Under Dynamic Conditions Using Barrier Films and Labyrinth Seals

35 Effects of the Space Environment on the Properties of Specific Polymers

INDEX OF MATERIALS TECHNOLOGY

	METALS		CERAMICS		POLYMERS		COMPOSITES	
	TECH REQ'S	FLIGHT EXP'MTS	TECH REQ'S	FLIGHT EXP'MTS	TECH REQ'S	FLIGHT EXP'MTS	TECH REQ'S	FLIGHT EXP'MTS
DEVELOPMENT SYNTHESIS IMPROVEMENT	1, 2, 3, 5, 9, 14, 18, 49, 50, 51	9a, 49, 50, 51	24, 25, 26, 52	52	27, 28, 29, 30, 31, 32, 36, 40	28, 29, 30, 31, 32, 36	41	----
CHARACTERIZATION INSPECTION TESTING FAILURE ANALYSIS LIFE PREDICTION ENVIRONMENTAL EFFECTS	4, 5, 6, 7, 8, 9, 10, 11, 21	5a, 5b, 7, 9b, 10, 11, 21	----	----	33, 34, 35	33, 34 35	42, 43, 44	43, 44
MANUFACTURING PROCESSING FABRICATION JOINING	12, 13	12, 13	52	52	27, 28, 36	28, 36	45, 46	----
BASIC UNDERSTANDING	2, 9, 11, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	9a, 19, 21, 22	52	52	37, 38, 39, 40	----	47, 48	----

NUMERALS CORRESPOND TO DEFINITION OF TECHNOLOGY REQUIREMENTS LISTINGS. DUPLICATION OF NUMERALS IMPLIES EITHER MULTIPLE APPLICABILITY OR CANDIDATE FLIGHT EXPERIMENT.

CROSS INDEX OF MATERIALS TECHNOLOGY

MATERIAL / APPLICATION	METALS		CERAMICS		POLYMERS		COMPOSITES	
	TECH REQ'S	FLIGHT EXP'MTS	TECH REQ'S	FLIGHT EXP'MTS	TECH REQ'S	FLIGHT EXP'MTS	TECH REQ'S	FLIGHT EXP'MTS
STRUCTURES	3, 4, 6 7, 9, 10 11, 13, 15 17, 19, 20 21, 51	7, 9a, 9b, 10, 11, 13, 19, 21, 51	24, 25, 26		27, 28, 29 30, 32, 33 34, 35, 37	28, 29, 30 33, 34, 35	38, 41, 42 43, 44, 45 46, 47, 48	43, 44, 46
POWER	2, 5, 9 10, 12, 14 16, 18, 23 50	5a, 5b, 12, 50	24, 25, 52	52	29, 30, 31 32, 25, 36 39, 40	21, 32, 36		
PROPULSION	1, 8, 9 10, 22, 23 49, 50	22, 49, 50	24, 25, 52	52	27			

SPACE MATERIALS TECHNOLOGY REQUIREMENTS

Mission Driven

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 1

1. TECHNOLOGY REQUIREMENT (TITLE): Materials with High PAGE 1 OF 1
Thermal Conductivity and High Thermal Conductivity and High Strength at High Temperatures for Rocket Motor Nozzles

2. TECHNOLOGY CATEGORY: ______

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop new alloys (e.g., Copper-silver system) with higher strength at elevated temperatures (above 600°C) combined with high thermal conductivity to allow regeneratively-cooled liquid rocket engines to be run at higher stresses and, therefore, more efficiently.

4. CURRENT STATE OF ART: ______

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

A Metallurgical study of solution and particle strengthening across phase changes at high temperatures for the copper-silver-zirconium alloy system is needed. Perhaps tungstem or other refractory metals in solution would suffice. Of course, any particulate strengthening would have to be effective at high temperatures without causing low temperature embrittlement. The alloy must be castable, forgable and machinable in addition to the required physical and mechanical properties. If an alloy shows promise Space Shuttle Main Engine Nozzle forgings should be made for direct comparison with current engine hardware. A successful result could be incorporated as a running model change in SSME.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Regeneratively cooled, rocket motor nozzles are limited by heat transfer rate, hence thermal conductivity and thickness of the alloys used. Currently, copper alloys provide the maximum thermal conductivity but are lacking in high temperature strength. Higher strength and low cycle thermal fatigue resistance would allow the use of higher pressures and thinner walls for improved heat transfer and thermo-dynamic efficiencies, not to mention lighter weight and longer life. This is a case where small improvements in the high temperature strength of available alloys would produce a major cost savings.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2

1. TECHNOLOGY REQUIREMENT (TITLE): Higher Temperature Superconductors PAGE 1 OF 4

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop higher temperature superconductors to allow development of improved extraterrestrial power systems, space instruments, high-speed computers, and power transmission capabilities.

4. CURRENT STATE OF ART: Experimental superconductors have critical temperatures up to 23 K. Systems have only operated to 4.2K.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

Superconductors with critical temperature above 77K are highly desirable for a number of space applications. Currently, critical temperatures up to 23K have been shown in the laboratory, but only to 4.2 K in operating systems.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a.) Improved superconductors with transition temperatures significantly higher than 20K would beneficiably impact a variety of space-related fields, particularly by reducing the bulk and cost of the required refrigeration equipment. Currently available superconductors require cooling to liquid helium temperatures; increases in the transition temperatures for useful superconducting materials to liquid hydrogen or liquid nitrogen temperatures would be quite advantageous.

b.) Superconductors are important components in a variety of applications. In the power field, magnetohydrodynamic and certain fusion power system concepts require strong field deriveable from superconducting magnets. The potential development of anti-matter power systems in the next century also should benefit from improved superconducting magnets.

The speed and capacity of large computers is greatly increased through the use of superconductors to transmit information bits. This application is currently receiving attention for ground-based computers where the size of the refrigeration equipment is not a major problem. Increased superconducting transition temperatures would reduce the size of the required refrigeration equipment and enhance the use of higher-speed larger-capacity computers in space. TO BE CARRIED TO LEVEL __

(See attached sheet)

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2

1. TECHNOLOGY REQUIREMENT(TITLE): Higher Temperature Superconductors

PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

The strong electron-phonon coupling which promotes superconductivity at very low temperatures also contributes to loss of superconductivity at higher temperatures. There are physical reasons for believing that superconductivity may not be attainable above 40K in alloys or compounds.

9. POTENTIAL ALTERNATIVES:

Use of available superconductors with large refrigeration systems is the only apparent alternative.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 2

1. TECHNOLOGY REQUIREMENT (TITLE): Higher Temperature Superconductors — PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

1.) Outlook for Space, NASA, July 15, 1975.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

(continued)

6. There are a large number of particle and radiation detection instruments dependent on magnetic fields which would benefit from improved superconductors. These applications include spectrometers, radio telescopes, Josephson effect detectors, and others.

The advent of higher temperature superconductors would impact also on power transmission applications. These applications would include large solar power collection systems in space and routine transmission of large amounts of power on earth.

c.) Quantitative description of systems improvements is not possible at the present time.

d.) The advent of 77K-plus superconductors would significantly reduce the weight of the required refrigeration system and improve the efficiency of various superconducting components. New alloys and compounds would be fabricated by various techniques, including splat-cooling to obtain metastable structures. These materials would be characterized in terms of their transition temperatures and other electrical and magnetic parameters. Techniques for fabricating the most attractive materials into usable forms, such as clad cable, would be developed.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 3

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Lunar Extractive Metallurgy (low priorities)

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop new or modified processes for extraction of Al, Mg, Fe, Ti, Si, Th, ceramics, and glasses from Lunar materials.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Justification and Scope: The orderly exploration and explortation of our Solar System is anticipated to include the establishment of a Lunar Colony, small (3-12 men) at first but increasing with time into a much larger permanent base. (100 plus men) The time scale suggested by von Puttkamer envisions the establishment of the larger Lunar Colony by about the year 2000. This colony will become increasing more self-sufficient with time, relying on lunar minerals as sources for oxygen and constructional materials and becoming gradually independent from supplies shuttled from Earth.

Initially, it is expected that the lunar fines can be sentered or melted and cast into useful forms. Ultimately, materials such as Al, Mg, Fe, Ti, Si, Th, ceramics, and glasses will need to be extracted from lunar minerals. These extraction processes will be considerably different from those (Continued)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 2

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 2 OF 1

Lunar Extractive Metallurgy (low priorities)

(Continued)

5. developed for Earth use due to the considerably different environment (hard vacum, 1/6 G) and high cost of supplies such as water and power. The probable complexities of such novel, lunar extractive processes strongly suggest early initiation of developmental studies on Earth to assure their timely availability.

It is anticipated that a 2 man yr/yr effort over a 5-year period should be sufficient to identify the most promising lunar extraction techniques. Subsequent effort would then depend on the extent of further development required and the then current time frame for Lunar colonization.

Approach: Simulated lunar minerals would be crushed and treated by a variety of mechanical, electrical, and chemical processes to yield products amenable to metal extraction. The processes most useful on Earth for extracting the various metals of interest would serve as starting points, modified as necessary to reflect Lunar conditions.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 4

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 2

Environmental Interactions - Meteoroids and Radiation

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Continue to collect and assess data on the nature and magnitide of meteroid and space radiation effects on metals during space travel and on nuclear radiation effects on metals from radioisotopes and reactors.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Meteoroids. While meteoroids constitute a potentially damaging hazard in space, the measurements and experiences to date strongly suggest that, in actuality, the danger is not as great as was originally expected. This variation between expectations and experience is attributed largely to the difficulty of obtaining reliable data on the frequency, size, density, velocity, and distribution of meteoroids. Concern is lessened since it is probable that no more than one spacecraft has been lost during the past 17 years to meteoroid impact. Currently, the need is for better data so that spacecraft can be more properly designed rather than overdesigned for the desired degree of meteoroid protection.

(Continued)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Data on meteoroid and space radiation characteristics and effects on materials must continue to be analyzed as they are accumulated. Specific significant problem areas must be addressed if and when they are identified.

Nuclear radiation effects on materials must also continue to be analyzed. The nuclear environments expected in actual reactor applications must be simulated as best possible during experimental exposures in order to produce applicable results. In particular, the effects of fast reactor exposures must be accurately characterized.

TO BE CARRIED TO LEVEL

5.

Space Radiation. Space radiation hazards consist primarily of solar flares (protons and helium nuclei), cosmic radiation (largely protons and helium nuclei), and radiation belts surrounding Earth, Jupiter, and Saturn (protons and electrons). These radiations, particularly solar flares, can be hazardous to life, but their effects on materials are generally minimal, except possibly for electronic materials. As for the meteoroid problem the current need is for more definitive data on space radiation effects to allow the design of proper protection, when needed.

Nuclear Radiation. In contrast to space radiation and meteoroid effects, the effects of nuclear radiation on near-by materials are generally significant. These effects include degradacion of mechanical properties (embrittlement and loss of strength) and transmutation to other elements. For in-reactor materials, shielding is not possible and contructional materials must be selected based on known radiation effects and design limitations. Shielding is of course possible for the protection of near-by out-of-core materials, but here too it is desirable to employ materials exhibiting minimal effects. The efforts which have been on-going on characterization of radiation effects need to be continued and modified as requirements and environments become better defined.

The estimated level of effort is a continuing 1-2 man yr/yr effort on analysis of potential meteoroid and space radiation effects on materials and a continuing 5 man yr/yr effort on analysis of nuclear radiation effects on materials.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 5

1. TECHNOLOGY REQUIREMENT (TITLE): Development and Characterization of Refractory Metals for Space Power Systems PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Structural and Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop new alloys of Cb, Ta, Mo, W, and Re, characterize their properties, and develop appropriate fabrication techniques to support the development of extraterrestrial nuclear power and propulsion systems.

4. CURRENT STATE OF ART: Many refractory alloys have been developed but are inadequately characterized for long-time service. Specialized fabrication techniques need to be developed some applications. HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The short time creep behavior of most refractory alloys has been characterized. However, the long-time behavior (>1000 hrs.) needs to be better characterized, particularly as affected by grain size, contamination, and corrosion. Corrosion reactions with liquid metal working fluids need more study, particularly as affected by contamints and impurities, for loops and heat pipes. Sputter yield data is needed for refractory and other alloys to assist in the selection of materials for use in plasmas, such as in electric thruster and MPD propulsion systems. Specialized fabrication techniques need to be developed for fuel clads and heat pipes. Some of these applications will likely require additional alloy development.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

(a) Two payload experiments are suggested in the refractory metals area:
   1. Determination of space contamination effects (from near-space residual gases) on operation of refractory metal/liquid metal heat pipes; and
   2. Determination of space contamination effects on creep properties of refractory metals.

   In both of these experiments, retention of useful strength for long time (several years) is the critical parameter.

(b) Further development of refractory metals technology will benefit nuclear fission, fusion and radioisotope power systems, various advanced propulsion systems such as electric thrusters, and high-temperature heat pipes for various applications.

(c) For most of these refractory metal applications, quantitative improvement parameters cannot be given because the systems are in such early stages of development. In general, refractory metals are required to assure.

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 5

1. TECHNOLOGY REQUIREMENT(TITLE): Development and Characterization of Refractory Metals for Space Power Systems

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

9. POTENTIAL ALTERNATIVES:

The problem of space contamination of refractory metals may be at least partially alleviated through the use of shields.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

The long time creep behavior of columbium alloy C - 103 is being studied in support of the Mini-Brayton Radioisotope Power System (2 KWe) under RTOP 506-23-4

EXPECTED UNPERTURBED LEVEL 7

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 5

1. TECHNOLOGY REQUIREMENT (TITLE): Development and Characterization of Refractory Metals for Space Power Systems

PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES																		

14. REFERENCES:

1. Outlook for Space, NASA, July 15, 1975

2. W.D. Klopp, LeRC, Aug. 12, 1975

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

6. (continued) adequate system lifetimes.

(d) Ultimately, the development and characterization of refractory alloys must be carried to Level 10, "lifetime extension of an operational model." This will require several decades of development and operating experience in the intended applications.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 6

1. TECHNOLOGY REQUIREMENT (TITLE): Fracture Toughness/ Strength Optimization of High Strength Structural Alloy Systems PAGE 1 OF 2

2. TECHNOLOGY CATEGORY: (9) Structural and Spacecraft Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Improvement in fracture toughness of medium-high strength structural alloys $K_{Ic}/\sigma YS \geq 1$ for ferrous alloys and titanium alloys

4. CURRENT STATE OF ART: $K_{Ic}/\sigma YS \approx .5$ (ferrous alloys) $K_{Ic}/\sigma YS \approx 0.75$ titanium alloys

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Structural metal alloy systems have reached a highly matured state of development in achieving high static strength levels through alloying additions and process treatments. However, the utilization of materials at high static strength levels has resulted in problems of fracture control of hardware where failure is manifested by defect or crack instability. Higher strength levels have generally been accompanied by lower fracture toughness properties in a given alloy system. This in turn can result in fracture instability at smaller defect or flaw sizes more difficult to identify through inspection techniques. The utilization of materials in this high strength condition has resulted in service failures which currently force the design specialist to sacrifice strength in order to achieve some desirable fracture control. (continued)

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Improvements in fracture toughness of high strength structural metals in the near term will be obtained by a more thorough understanding of the micro-mechanical processes governing crack instability in given alloy systems and subsequent optimization of thermal and mechanical treatments and more complete characterization of strength-toughness properties over the entire range of conditions obtainable. This will be accomplished largely through experimental programs. Improvement of fracture toughness of high strength materials over the long term will require advanced alloy development programs.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT

NO. 6

1. TECHNOLOGY REQUIREMENT (TITLE): Fracture Toughness/ Strength Optimization of High Strength Structural Alloy Systems

This design rationale now dictates a weight penalty in primary structure and tankage materials in the Space Shuttle and could have similar impact on advanced space transportation systems.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 7

1. TECHNOLOGY REQUIREMENT (TITLE): Utilization of Magnesium Beryllium and Beryllium-Aluminum Alloys in Advanced Space Structure PAGE 1 OF 1

2. TECHNOLOGY CATEGORY: (9) Structural and Spacecraft Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To provide additional data base relating to secondary design considerations for use of thin gage, light alloys in advanced spacecraft application

4. CURRENT STATE OF ART: Utilization of alloys 0.5 - 1.0 mm thick in non-space environments

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The need for high stiffness critical large space structure for application as antennae members, space station components, and power generation components will require additional development and chacterization for beryllium and beryllium-aluminum alloys.

The high stiffness/density ratio beryllium and beryllium-aluminum alloys coupled with the potential for utilizing metals and joining technology make these alloys strong candidates for stiffness critical members of large space structures.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Deficient technology areas include process optimization for reducing costs, understanding and dealing with potential toxicity problems, and expanding the data base for secondary design considerations including earth environment time dependent processes of corrosion and fatigue, and improvement in toughness of these alloys.

Identification of high cost process variables and optimization of manufacturing technology for frabricated hardware is necessary, and experimental programs to characterize material performance under mission simulation requirements should be conducted. A development program for improved toughness of these alloys should include thermo-mechanical processing techniques.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 8

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Low Cycle Thermal Fatigue of Superalloys

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop data on low cycle thermal fatigue of currently available alloys over range of casting, forging and heat treating conditions for extending life of turbo pump components in high-pressure liquid rocket motors.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Data are required to determine maximum temperature operation in air oxygen and hydrogen, at reversed stresses into the plastic zone of super alloys such as Incoloy 713 C and Mar M 246 for use in nozzles, rotors and blades of high-pressure turbo-machinery. Even minor improvements of Space Shuttle Main Engine life based on a firm prediction of material characteristics will result in major cost savings.

Scope: The large number of specimens necessarily requires that this program will take at least 2 years and employ some very specialized test apparata for the high pressure phase, at least.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Space Shuttle Main Engine and other Advanced flight-weight turbo-pumps have a limited life because they are often stressed to near-yield on each run-up at the same time they are exposed to maximum operating temperatures and an embrittling environment such as hydrogen gas at high pressure. Simple improvements in heat-treatment, surface conditioning or coatings could greatly increase life. Even an understanding of what variable in the environment is the most deleterious could lead systems designers to optimize conditions for improved cyclic life. This is a case where a better understanding of available alloys would be helpful.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 9

1. TECHNOLOGY REQUIREMENT (TITLE): Fatigue, Fracture and Life Prediction of Metallic Structures Exposed to Chemical Environments. PAGE 1 OF 4

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop an adequate understanding of the time dependent interaction of chemical environments with metallic materials such that the life-time of space related structures may be extended and/or their failure may be accurately and reliably predicted. (Cont'd)

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

If we are to reliably and accurately predict the life of metallic structures exposed to space related, chemical environments, we must develop the basic understanding of the kinetic and mechanistic aspects of both the interaction processes and the processes by which degradation can occur. Because these are complex problems we must use an ordered approach; first developing our technology on the simplest alloy systems in the more complex and combined environments as indicated in the enclosed flow chart. Simultaneously we must maintain our ability to develop immediate solutions to specific engineering, chemical compatability problems.

Our goal must be to develop the basic understanding of the chemical interactions and the processes of degradation. With this, we will be able to develop accurate and reliable, quantitative models for life prediction, to select optium alloys and microstructures for use in space related chemical environments and to develop our potential to design alloy systems for use in space and planetary environments.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

As the use of space increases, the demands on materials will become more and more severe. Payload sizes will grow and the need for light weight, high strength structures will increase. Some will require reuse. Flight durations will increase extensively with corresponding increases in the length of environmental exposure. Comet and asteroid rendezvous and planetary entry and exploration will become realities. Such increases in the profiles of the missions will demand an increased understanding of, and the ability to predict, the potential degradation of structural materials exposed to potentially aggressive chemical environment be they gaseous, liquid or solid.

Under the present mission model, our lack of understanding and our inability to accurately predict the potential degradation of metallic structures exposed to potentially active chemical environments limits the efficient utilization of materials. For example the use of light weight, high strength titanium alloys or high strength steel alloys to replace the less efficient aluminum structures is limited by our knowledge and ability to control their degradation by simple chemical environments such as salt water, humidity, or gaseous hydrogen.
(Cont'd)

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 9

1. TECHNOLOGY REQUIREMENT (TITLE): Fatigue, Fracture and Life Prediction of Metallic Structures Exposed to Chemi^al Environments. PAGE 2 OF 4

3. (Continued)

Chemical environments include gas, liquid and solid phase environments such as those anticipated to be encountered on earth, in space and during planetary entry and exploration. To be identified are the specificity of the interactions; the kinetic influences of temperature, pressure and potential synergistic effects fo combined and/or changing environments; and mechanisms of degradation including the influences of metallurgical parameters such as microstructure and alloy additions and external parameters such as mode of loading and degree of stress triaxiality in order that the optimum material can be selected for the specific space related applications.

6. (Continued)

In general, predictive models for flaw growth in aggressive chemical environments are non existent. Even our ability to accurately identify critical structural areas which may require continued monitoring or refurbishment in reusable structures is many times lacking.

In low-earth-orbit transportation systems the use of heavy hydrocarbon propellants to replace sold propellants will require a significant technological advance in our ability to predict the behavior of light weight, high strength metals as reusable tankage. Even our ability to accurately predict the life-time of a light weight, reusable hydrogen tank is lacking.

The safe removal of many hazardous payloads from earth will require a significant advance in our understanding of the interaction of a metal with its chemical environment. As an example, nuclear waste disposal will require containment of severely chemically aggressive material with total and complete assurity even during a launch pad abort or a mission abort and return to earth. Similar problems are found to exist in the transport of nuclear systems into space for space power and propulsion or for power generation for use on earth. Such applications of materials will require complete and accurate life prediction models which presently are not available.

During extended missions, where times become very long, material combinations which are normally considered compatable may be found to be incompatable. Problems may be encountered not only in the long term storage of active propellants such as ammonia or metastable hydrogen but also in the compatability of normally consider safe interactions such as coatings, platings, or any area in where dissimilar metals may be in contact. For very long time life-prediction the time dependent interactions of active environments must be totally understood in order that accellerated testing techniques may be developed to reliably predict the life-time of metallic structures in contact with chemical environments normally thought to be non-reactive.

The anticipated rendezvous with comets and asteroids and planetary probes landers and rovers will require a significant technology advance in our (Cont'd)

6. (Continued)

understanding of materials compatability. As an example, the life time of most efficient structural metals exposed to these potentially severe conditions of pressure, temperature, ad corrosive environment can not presently be predicted.

Finally, our materials technology has been primarily designed for use in the chemical environment of earth. This technology may not be the best for materials use in the total chemical environments of space, the moon or other planets. Many alloy systems which have proved to be poor performers or which would never be considered for development on earth may perform very well in the special chemical environments encountered in space. As an example, alloy systems having major or minor concentrations of the earth-reactive elements of Lithium, sodium, potasium, and others may yield unique properties which could not be obtained and in fact may never have been considered through the use of our earthbased technology. Such systems should be explored in detail for the more efficient use of materials in space.

DEVELOPMENT OF AN UNDERSTANDING OF FATIGUE, FRACTURE AND LIFE PREDICTION IN SPACE AND SPACE RELATED CHEMICAL ENVIRONMENTS

Immediate solutions
to specific engineering, chemical
compatibility problems

simple engineering alloys
(Al, Fe, Ni, etc.) exposed to
simple pure environments
(H_2, Na, Zn)

Advanced engineering alloys
(Ti, U, Si, etc.) exposed to
simple pure environments

engineering alloys exposed
to complex pure environments
(H_2O, heavy hydrocarbous, metastable
hydrogen, etc.)

engineering alloys exposed
to combined environments
(aqueous chloride, heavy
hydrocarbous with contaminates, etc.)

Basic understanding
of interaction kinetics
and kinetics and mechanistic
aspects of degradation

Accurate and reliable
Models of Life prediction

Design of more
insensitive alloys
and microstructures

Design of alloys
to be used solely
in space and planetary
environments.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 10

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 2

NDT/NDE - Earth and Space

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To advance the technology of non-destructive methods for the detection and evaluation of (Cont'd)

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

The probability of detection and the estimate of flaw size vary with the non-destructive technique employed and the size and nature of the flaw. Moreover, the human factor carries a very high weight in such determinations.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Specimens representing different geometries containing defects of various types and sizes will be examined non-destructively in both space and earth environments in order to determine, on a probability basis, the lower limit of flaw detection and flaw size and shape. After such evaluations, the specimens will be destructively examined in order to determine the exact nature of the flaws.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 10

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 2 OF 2

NDT/NDE - Earth and Space

3. (Cont'd)

macroscopic flaws in metallic materials with primary emphasis on standardization of procedures and interpretation and quantization of results, and to incorporate such information within design, manufacturing, and service stages of components and structures.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 11

1. TECHNOLOGY REQUIREMENT (TITLE): Development of Elastic-Plastic Failure Criteria PAGE 1 OF 2

2. TECHNOLOGY CATEGORY: ______

3. OBJECTIVE/ADVANCEMENT REQUIRED: To establish the dependence of the degree of stress triaxiaility and other factors which promote plastic behavior on the subcritical flaw growth in space related metallic structures. (Cont'd)

4. CURRENT STATE OF ART: ______

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

In a number of space related structures, materials and/or designs will be employed in which local yeilding of the structure will occur prior to failure. Examples of such structures include, but are not limited to large, thin wall, space tankage. Under such conditions, it is imparative to quantitatively understand the influence of localized plastic behavior on the time dependent parameters of subcritical flaw growth rate and strain-energy release rate. Such parameters are required in order to accurately and reliably predict the lifetime of a specific metallic structure and to reliably predict its mode of failure, i.e., leakage or catastrophic fracture. Such criteria presently are not available. Additionally, a knowledge of elastic-plastic behavior will permit a better prediction of the critical monitoring points which will indicate the need for refurbishment in reusable space structures.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

To adequately predict the elastic-plastic behavior of most structural members in space, we must develop accurate and reliable failure criteria. In order to do this, the contribution of plastic zone size or degree of stress triaxiality to the rates of subcritical crack growth and energy release must be established as a function of both material and configurational parameters. Mechanical strength and ease and form of plastic deformation are examples of material parameters, while wall thickness is a configurational parameter. From this knowledge standardized test techniques can be established and an accurate and reliable failure criteria can be developed.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 11

1. TECHNOLOGY REQUIREMENT (TITLE): Development of Elastic-Plastic Failure Criteria — PAGE 2 OF 2

3. (Cont'd)

To develop the quantitative understanding required for predictive models which may be used to establish elastic-plastic failure criteria as applied to unique space structures, such as thin wall containers, in an effort to better understand the conditions underwhich leakage or rapid failure may occur.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 12

1. TECHNOLOGY REQUIREMENT (TITLE): Solar Cell Solder Connections with Extended Life During Thermal Cycling in Orbit PAGE 1 OF 1

2. TECHNOLOGY CATEGORY: ____________

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop an improved joint-solder combination for silicon solar cells to eliminate embrittlement by inter-metallic compound formation and, thereby withstand prolonged thermal cycling in orbit.

4. CURRENT STATE OF ART: ____________

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Currently, lead-tin solder reacts with silver and titanium barrier and contact layers causing embrittlement and mechanical breakage of individual joints resulting in reduced power output with time in orbit.

A study of the compatability and reactivity of metals in the contact, barrier and solder to eliminate formation of embrittling inter-metallic compounds will lead to new barrier layers or improved solders for solar cells.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Solar cell arrays operating in earth orbit go through a large thermal gradient as much as 120°C from sun to earth shadow. Most of the effects of the thermal gradient can be accounted for in designs (e.g., thermal expansion) but embrittlement of the solder joint to the contact layer on the cell cannot. Hard inter-metallic compounds are formed by diffusion which become loss in power output. Heretofore, large solar arrays (skylab, HEAD, etc.) have been over-designed in expectation of reduced output with time. However, longer life and increase of power requirements for energy programs in space or on earth will preclude such a cavalier treatment of the problem. This can be solved by careful attention to the metallurgical bond in the joint and barrier layer.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 13

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Joining Metals in Space

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To easily and reliably produce strong metallurgical bonds for the space assembly of metallic structures by utilizing cold resistance, and explosive welding techniques.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

The placement of very large structures in space, e.g., antennae, solar cell arrays, etc., necessitates their fabrication "in-situ." Thus, modular subsystems or individual components must be joined in the space environment.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

In the case of cold welding, clean metal surfaces are brought into intimate contact under moderate pressures which are less than those required to produce yielding. Slight relative displacements of the mating surfaces are employed to insure proper contact. Resistance welding may be accomplished in much the same way although the temperature of the joint is elevated by the passage of electric current. In the case of explosive welding, a contained explosive seam welding technique will be employed.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 14

1 TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Studies of Electromigration in Metals and Alloys

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To obtain a basic understanding of of the electromigration process in metals and alloys in order to provide guidance in the alleviation of the phenomenon as it occurs or will occur in microcircuitry.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Theoretical and experimental studies extending present work.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The electromigration phenomenon occurs at high current densities such as those found in connecting elements in microcircuits ($\sim 10^6$ amp/cm^2). Under conditions of high current density mass displacement occurs and breaks can form in the connectors. Theoretical studies have defined the phenomenon to a degree and steps to alleviate the problem have been successful in circuits of the present state of miniaturization. It is anticipated that the problem will arise again as reductions in circuit size occur. The research should be supported at least at its current level.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 15

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Theoretical Studies of Diffusion in Alloys

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop a quantitative theory of diffusion in alloys that will permit prediction of diffusion rates in alloys of applications interest.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Studies including

1. Calculation of energy of formation and number of vacancies.
2. Definition of elementary jump processes in ordered and unordered systems.
3. Relation of bonding energy and activation energy for diffusion.
4. Impurity diffusion.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The wide variety of solid systems for which the ability to quantitatively predict diffusion behavior is needed suggests that the need for basic research in this field will be long-standing. At present the capabilities of prediction in the field of alloys is very sketchy. The desirability of predictive capability is obvious in terms of the costs and the difficulty of experimentally determining diffusion data.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 16

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Studies In Catalysis

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To obtain a fundamental understanding of catalyst structure and the mechanism by which catalysts function in order to provide guidance for formulations for fuel cell oxygen electrode, propellant catalysts and life support gas conditioning.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Studies including

1. Theoretical specification of compounds having D-band structures like those of active transition metals.
2. Effect of purity, surface area and surface plan orientation on catalytic efficiency (possible space preparation of samples)
3. Studies of the nature of active sites.
4. Theoretical calculation of potential distribution and absorbed molecule configuration for surface having absorbed molecules.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The mode by which a catalyst functions in terms of an atomic or molecular mechanism is still unknown. Recent theoretical research in two areas gives promise of enlightment. One is the calculation of the perturbation of the interatomic potential in the surface as an atom or molecule approaches. Indications are that alterations result in the electronic structure of the absorbed species in a way that would increase it's chemical reactivity. The other theoretical approach propose that the d-band structure of catalystic metals can be duplicated in compounds such as carbides. The test of this hypothesis is worthy of substantial support. Finally, new methods of preparation of catalyst metals if high purity and fine subdivision should be used and their effects investigated.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 17

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Studies of the Mechanisms of Hydrogen Embrittlement

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop fundamental understanding of the solid state and surface chemical processes that are involved in the hydrogen embrittlement phenomens on order to provide guidance in prediction or elimination of undesirable effects.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Studies such as

1. Theory of Hatom-dislocation interactions
2. Study of Hatom interaction with the crack tip
3. Mechanism of hydrogen dissociation on surfaces-catalysts and poisons
4. Mechanism of delayed fracture.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The problem of hydrogen embrittlement presents itself in a wide variety of situations. A nonexhaustive list includes stress corrosion cracking, of titanium by alcohols, delayed fracture of Nickel bearing materials exposed to hydrogen, fracture of hydrogen containing tankage and piping. The wide variety of phenomona in which hydrogen plazsa role implies a multiplicity of mechanisms. Both theoretical and experimental studies are needed and should involve multidisoplinary approaches by physicists, chemists and metallurgists. The present expenditure of effort by NASA should be augmented.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 18

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Studies of New Concepts for Solar Cells

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To examine relevant physical phenomena in order to develop more efficient methods for conversion of solar energy to electricity.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Studies such as

1. Electron-phonon interactions in semiconductors
2. Study of sensitized optical absorption by dye incorporation or other methods.
3. Investigation of applicability of materials other than silicon-e.g., gallium arsenide.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The direct conversion of solar energy to electricity has many advantages in terms of simplicity both in structure and size. The main disadvantage is the low efficiency imposed by the limited wave length bond involved. The cost is also a limiting factor and will increase an importance as larger space structures are considered. At some time the cost of development of solar cell materials other than silicon (whose development costs were mainly borne by other application needs) will become reasonable in the face of factors like larger demand. Gallium arsenide is a possible candidate. Demands for lower costs should also spur basic investigation of the increase of usable spectral width by the use of dye sensitization and perhaps other means.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 19

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Solid State Diffusion Studies in Space

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To obtain diffusion data for systems requiring very high temperatures and containerless conditions for the purpose of information on high temperature materials.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Diffusion experiments involving exposure of samples at high temperature in the absence of container materials. Sectioning and analysis to be performed on return to earth.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Diffusion experiments are normally limited to a temperature range whose lower limit is governed by reasonable time and whose upper limit is governed by available means for heating as well as problems of sample interaction with container materials. The zero gravity and high temperature capabilities in space are especially useful for diffusion studies in high temperature materials. The results would be of great value because

1. They would eliminate the need for inaccurate extrapolation of long time, low temperature experiments and
2. They would make data available for the investigation of possible changes in diffusion mechanism at high temperatures.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 20

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Experimental Studies of Diffusion in Alloys

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To provide diffusion data for test of theoretical formulations and to generate a fund of data for systems of practical interest.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

Well-controlled diffusion experiments designed to provide diffusion constants and actiration energies in a variety of alloy systems.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The needs for carefully obtained diffusion data are twofold. The first is for the development and verification of theoretical formulations. The second is for the generation of data for systems of frequent interest.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 21

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Phase Diagram Studies in Space

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED:

To perform phase diagram studies of phase relation shifts resulting from low pressure.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Construction of phase diagrams by exposure in space and analysis on return to earth. Systems to be studied initially would be for experimental convenience. Later studies on systems of importance to space processing.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Experience with vacum melting has shown that under low pressure, phase relations shift enough from those indicated in phase diagrams determined at one atmosphere to cause non-homogeniety and gas bubble formation. It is expected that the problem will also exist in space processing. Construction of the pertinent portions of the phase diagram must be done in space because the gravitational effects on the sample generate pressures which can not be tolerated.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 22

1. TECHNOLOGY REQUIREMENT (TITLE): Measurement of Vapor Pressure of Corrosive Materials (Space Experiment) PAGE 1 OF 1

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To provide thermodynamic prcperty data for nonmetallic materials whose corrosiveness requires that the measurements be done with levitation and with no container contamination.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Langmuir vaporization rate studies compiled with mass spectrometric identification of vaporized species. Specimens to be heated and exposed to high vacuum by shielding from spacecraft outgassing.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

There are many materials whose vaporization modes or themodynamic properties are poorly known because of their interaction with container materials. One example is sodium sulfate which is a critical factor in the hot corrosive phenomenon: widely varying data are obtained with various container materials. It is of great importance to the solution of the hot corrosive phenomenon to obtain better data. Hot corrosion of the extreme concern for aircraft turbine brackets, marine turbines and terrestrial power stations.

The need for data obtainable by this experimental technique can be cited for other instances as well.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 23

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Studies of Gas-Surface Reactions

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To gain an understanding of the details of the interaction of gas molecules with solid surfaces.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Studies such as:

1. ESCA and Auger studies of chemisorbed films
2. Rate measurements using microbalance
3. Mass spectrometric analysis of volatile reaction products of surface reactions.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The interaction of material surfaces with the environment is of manifest interest in widely varying circumstances--from the entry of the spacecraft into the atmosphere of Venus or Jupiter to the oxidation-corrosion of terrestrial devices. New instrumentation is providing means for gaining a better microcopic understanding of the details of phenomena such as chemisorption and physisorption, both of which are steps in gas-surface reactions. It is now possible to qualitatively, and in some cases quantitatively, determine the nature of the adsorbed layer (both identify and valence state), the distribution of the various species over the surface, as well as in cross section, and the rate of deposition. (Research of this type is also of importance to the understanding of catalysis.) Research in this area should be supported and augmented.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 24

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

High Temperature Insulations

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To provide the technology for improved high temperature insulations.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Improvements in space power, propulsion, and re-entry systems could be achieved in part with new or improved high temperature insulating materials. Power and propulsion systems can perform more efficiently at higher temperatures, but the associated hardware will need to be protected. Advanced space transportation systems and planetary probes also require higher temperature insulating materials between the TPS and the load-bearing structure.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Low thermal conductivity materials should be investigated for their thermal and mechanical properties at temperatures above 1200 degrees C, the limit of current insulations. These studies should be conducted at temperatures up to 1800 degrees C, or where radiative heat transfer predominates over conduction. Refractory additives should be investigated that may block radiative heat transfer. Candidate materials for investigation should include zirconia, hafnia, the refractory metal carbides, nitrates, borides, the zirconates, titanates, and the silicates of the refractory systems should then be studies for their fiberizing qualities with the goal of producing fibers with diameters less than 5 mils.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 25

1. TECHNOLOGY REQUIREMENT (TITLE): Structural Ceramics PAGE 1 OF 1

2. TECHNOLOGY CATEGORY: ______

3. OBJECTIVE/ADVANCEMENT REQUIRED: ______

To improve the thermomechanical properties of refractory ceramics.

4. CURRENT STATE OF ART: ______

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Much progress has been achieved in recent years in improving the performance of ceramic materials for gas turbine applications. These improvements have been primarily due to improved methods for designing with brittle materials and to careful processing methods for controlling the microstructure of refractory ceramics. These approaches should be applied to those materials that are of interest to space systems. Materials of interest are the refractory carbides, nitrides, alumina, beryllin, and carbon composites.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Advanced space transportation systems require improved oxidation resistant, high temperature materials for nose caps, leading edges, and propulsion systems. Nuclear power systems need tougher, shock resistant ceramic fuel elements.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 26

1. TECHNOLOGY REQUIREMENT (TITLE): Ceramic Fibers for Composites PAGE 1 OF 1

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Provide fibers having low coefficients of thermal expansion (CTE) for composites for large space structures.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Three classes of materials are known to possess low thermal expansion coefficients--graphite, amorphous silica, and lithium aluminum silicates. Additional material systems should be sought. Variations in each of these systems should be synthesized and processed under different conditions. These materials should also be characterized for their CTE as a function of modulus and strength. The CTE of graphite may be lowered to oil CM/CM/OK or less with new precursers. Heat treatments may lower the CTE of silica also to oil or lower. A negative CTE may be desirable to compensate for a positive CTE of the matrix. The lithium aluminum silicate system should be studies for this application.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Missions in the 1985-2000 period will require structures for observational purposes on the order of 100 to 1000 meters in length or diameter, and with stability between major elements in the millimeter to centimeter range. Such large structures, in addition to being light weight, low cost, stable for long times in the space environment, must be thermally inert. Several ceramic systems are potentially promising for these requirements and should be investigated.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 27

1. TECHNOLOGY REQUIREMENT (TITLE): — PAGE 1 OF 4

Large Area Polymer Films for Space Applications

2. TECHNOLOGY CATEGORY: Propulsion, Structural & Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: The objective of this program is to evaluate, adapt, and develop processes for the fabrication of large-area, thin polymer films for space applications.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

See Page 4

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The Office of Space Science (OSS) has indicated the need for a solar sailing spacecraft with the ability to gain 10 to 50 Km/sec. additional speed after Earth departure. This type of propulsion would be used in Comet and Asteroid Rendezvous and Sample Return Missions and would require the utilization of a large area, thin polymer film for the solar sail.

The Aerospace Corporation input to the current OASR workshop has stated the need for large area (200m2) polymer films for substrate membranes in unfolding antennas and for large diameter space mirrors.

Polymer films with the large areas required are not presently available and will require development and adaptation to meet the requirement for such applications.

TO BE CARRIED TO LEVEL 5

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 27

1. TECHNOLOGY REQUIREMENT(TITLE): ______

Large Area Polymer Films for Space Applications

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

See Page 4

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Propulsion, Power, Structures

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 27

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 3 OF 4

Large Area Polymer Films for Space Applications

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Test & Evaluation			—	—	—	—													
2. Fabrication Development			—	—	—														
3. Handling Development					—	—													
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

a. OSS Technology Requirements Input ot OAST Workshop

b. Aerospace Corporation Input to OAST Workshop.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 27

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 4 OF 4

Large Area Polymer Films for Space Applications

Commercially available polymer films, such as Kynar, Mylar, Kapton, TFE Teflon, FEP Teflon and polyethylene will be evaluated for tear and tensile strengths as well as fold and crease resistance. Joining methods, including heat sealing, adhesive bonding and mechanical fastening, as applicable will be developed and evaluated for the fabrications of the large areas required. Selection and evaluations of coatings and coating application methods will be conducted to provide high radiation resistance, high thermal emittance and low solar absorptance to the films. In addition, packing and storage methods suitable for coated films of this type will be devised and studied.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 28

1. TECHNOLOGY REQUIREMENT (TITLE): Adhesive Bonding of Large, Erectable Structures In Space

2. TECHNOLOGY CATEGORY: Structural & Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: The objective of this program is to develop, evaluate ad demonstrate the materials, techniques, processes and equipment required for assembly by adhesive bonding of the constituent components of large, space-erectable structures.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

See Page 4.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The requirement for large, space-erectable structures for future space missions has been confirmed by the user community both within and without NASA. For example, the SPART Study indicated the need of such structures to satisfy example, some of the NASA technology targets, such as large observatories, industries and utilities. In addition, the Office of Space Science (OSS) has included such structures in the new technology requirements for the period 1985-2000 for missions involving deepspace radiometry, infrared interferometry and long baseline interferometry. These structures will be on the order of 100 to 1000 meters in diameter or length with a high order of dimensional stability and a long life expectancy. Further, the Office of Applications (OA) has stated their need for light-weight, large scale arrays for power transmission. The present program encompasses the development of adhesives and adhesive joining techniques to be used in the fabrication of these large structures in space. The advantages offered by adhesive joining over other joining methods are, (1) light weight (2) dimensional stability, (3) compatibility with light weight non-metallic and metallic structural elements, (4) ease of fabrication and (5) minimal tooling and equipment.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 28

1. TECHNOLOGY REQUIREMENT(TITLE): Adhesive Bonding of Large Erectable Structures in Space

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

9. POTENTIAL ALTERNATIVES:

For metallic, erectable structures - join by welding
For metallic and non-metallic erectable structures--mechanical fastening.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

See Page 4

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

Development of large, erectable, space structures for observatories, industries, utilities, deep-space radiometry, infrared interferometry, long baseline interferometry and arrays for power transmission.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 28

1. TECHNOLOGY REQUIREMENT (TITLE): Adhesive Bonding of Large Erectable Structures In Space PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Material Devel.																			
2. Technique Devel.																			
3. Joint Evaluation																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE																		TOTAL
NUMBER OF LAUNCHES																		

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

Terrestrial Effort
The requirement for long life in the space environment will necessitate the development and evaluation of new adhesive formulations Low outgassing characteristics in the hard vacuum of space will be a requisite not only for the maintenance of structural integrity, but also to minimize the contamination of critical surfaces, such as sensors, mirrors, and thermal control surfaces. Other requirements will include resistance to space radiation and the ability to cure properly in vacuum. It is anticipated that premixing and freezing of the adhesive will be necessary to avoid the necessity of mixing the resin and catalyst in space for some application. Thawing of the adhesive and its introduction into the joints in a weightless environment will require the development of special equipment and tools. For other applications, prepreg film adhesives will be used.

Typical, specimen joints will be made and evaluated for strength characteristics, dimensional stability, and resistance to simulated space invironments to select the adhesives for evaluation in space.

Space Effort
Further evaluation of the life characteristics of the selected adhesives will be accomplished by exposure of typical joints to the space environment on LDFF. Since a six-month exposure is not considered of sufficient duration, it is recommended that the LDEF mission be extended to 3 years duration so that joint specimens could be returned at various intervals throughout this time span by the Shuttle for evaluation of Earth.

The joints will be returned in evacuated, sealed cannisters and evaluated for strengtn capability and dimensional changes in evacuated chambers to avoid any Earth atmospheric effects. Such tests will generate data which will provide for more meaningful extrapolations for longer time periods.

Actual space demonstration of the developed bonding techniques and equipment will be conducted in orbit outboard the pallet of the Spacelab by experimenters equipped with space suits. Typical joints will be made in this manner and returned to Earth under protection in cannisters and evaluated for strength characteristics as described previously.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 29

1. TECHNOLOGY REQUIREMENT (TITLE): Long Life Polymeric Protective Coatings for Space Applications

2. TECHNOLOGY CATEGORY: Structures & Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop protective coatings of greater resistance to the space environment for use on solar cells, thermal tapes, circuit boards, etc.

4. CURRENT STATE OF ART: Protective coatings are available with various space compatibilities (outgassing, thermal, etc.) but are not consistant nor completely reliable.

HAS BEEN CARRIED TO LEVEL 2

5. DESCRIPTION OF TECHNOLOGY

Polymer chemistry has produced several protective coating materials that have been used in space applications with success as far as is known (we need recovered mechanisms to check out their success). The epoxies, urethanes, silicones, etc. need experimentation in space to determine their long life usefulness.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☒ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

a) Long life protective coatings are required for protection of external and internal items. Long life space test results are not available and must be obtained.

b) LDEF type long duration platform.

c) Long life mission performance will definitely be improved or assurance of the integrity (as to life) of the coating will be determined.

d) Long duration space flight is necessary in order to bring protective coatings to level 10.

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 29

1. TECHNOLOGY REQUIREMENT(TITLE): Long life Polymeric Protective Coatings for Space Applications

7. TECHNOLOGY OPTIONS:

To depend upon Engineering extrapolation of earth laboratory data to fulfill the longer life missions.

8. TECHNICAL PROBLEMS:

Polymer chemistry's investigation into new products and methods of synthesis of the material.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

To continue outgassing and contamination evaluation of present commercial products and extrapolation of the data to space applications.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 29

1. TECHNOLOGY REQUIREMENT (TITLE): Long Life Polymeric Protective Coatings for Space Applications PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis				—	—														
2. Development					—														
3. Testing						—													
4. Documentation						—													
5.																			
APPLICATION																			
1. Design (Ph. C)							—												
2. Devl/Fab (Ph. D)							—												
3. Operations								—			—								
4.									—			—							

13. USAGE SCHEDULE:

TECHNOLOGY NEED DATE					79												TOTAL
NUMBER OF LAUNCHES							1			1							2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 30

1. TECHNOLOGY REQUIREMENT (TITLE): Long Life Adhesives for Space Applications PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structures and Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop improved long life adhesives for use in space--solar cells, thermal tapes, structural honeycomb.

4. CURRENT STATE OF ART: Today's adhesives do a good job with occasional T/V failures. We do not know their 'space' durability as none have been recovered. HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

Polymer chemistry must develop adhesives that are 100% reliable after a long term space exposure (5-10 years) as S/C life times are in the 5-10 year range. Present day adhesive will fail occasionally in T/V testing or under ground assembly conditions. We do not know of their true space applicability as none have been recovered from space. The chemical-adhesive properties should be improved and long duration 'space' exposure is necessary.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

a) Present day technology is not 100% reliable. Better adhesives must be developed in order to assure us that our S/C missions will be 100% successful.

b) Long term exposure to 'space'--LDEF

c) Long life times and more assurance of payload mission success will be the end product of this effort.

d) 10

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 30

1 TECHNOLOGY REQUIREMENT(TITLE): Long Life Adhesives for Space Applications. PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

To continue as today with selection of adhesives being made as Engineering extrapolations from earth laboratory data.

8. TECHNICAL PROBLEMS:

Development of improved adhesives by polymer chemistry. It may not be possible to do so by rearrangement of the molecular structure.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Continued analysis of commercial data on new products plus outgassing, contamination, and other laboratory test data.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 30

1. TECHNOLOGY REQUIREMENT (TITLE): Long Life Adhesives for Space Applications PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Design																			
3. Development																			
4. Testing																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Documentation																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
TECHNOLOGY NEED DATE						1											
NUMBER OF LAUNCHES							1			1							2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 31

1. TECHNOLOGY REQUIREMENT (TITLE): High Temperature High Thermal Conductivity Polymeric Materials

PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structures and Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To increase the thermal conductivity of polymeric materials for use at high temperatures.

4. CURRENT STATE OF ART: High thermal conductivity is controlled by filling with metal powders. It is proposed that the thermal conductivity be improved by rearrangement of the molecular structure or by improved organo-metallic compounds.

HAS BEEN CARRIED TO LEVEL 3

5. DESCRIPTION OF TECHNOLOGY

The technology of polymer chemistry is involved as the means of improving the desired property of the polymers. The technology of thermal/heat transfer will be involved in testing and evaluation.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

a) In some cases (planetary probes) high temperatures are encountered and good thermal control is very necessary.

b) Long duration exposure facility with thermal control is required.

c) Will be beneficial to planetary probes and others where high temperatures are involved.

d) 10

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 31

1. TECHNOLOGY REQUIREMENT(TITLE): High Temperature High Thermal Conductivity Polymeric Materials PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

To continue to extrapolate laboratory data and to design other methods/materials for thermal control.

8. TECHNICAL PROBLEMS:

Polymer chemical structures- inherent thermal and physical properties of polymers.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

Continue to evaluate commercial products and to extrapolate laboratory data.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 31

1. TECHNOLOGY REQUIREMENT (TITLE): High Temperature High Thermal Conductivity Polymeric Materials PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Design/development																			
3. Testing																			
4. Documentation																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Documentation																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE						1												
NUMBER OF LAUNCHES								1		1								2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 32

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Electrical Conductivity Polymeric Materials PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structures and Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To significantly improve the electrical conductivity of polymeric materials.

4. CURRENT STATE OF ART: Electrical conductivity is improved in polymers today by the addition of metals (powders, fibers) to the polymeric materials. This should be investigated by rearrangement of the chemical structure if possible.

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Polymer chemistry must study and investigate the problem to determine how to increase the electrical conductivity of the material, by rearrangement of the chemical structure or some other such manner.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

Requires a long duration exposure facility to fully evaluate the end product. This product is needed to control the space change created in-flight spacecraft and other orbiting devices.

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 32

1. TECHNOLOGY REQUIREMENT(TITLE): Improved Electrical Conductivity Polymeric Materials. PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

To continue to develop 'fixes' for each condition as they arise by using Engineering Judgment and earth laboratory data.

8. TECHNICAL PROBLEMS:

Chemistry of polymers--may not be able to rearrange the chemical structure to achieve the objective.

9. POTENTIAL ALTERNATIVES:

Use present day materials and rely on 'fixes'.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

To look at the problem on a very low priority basis, maybe never.

EXPECTED UNPERTURBED LEVEL 3

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 32

1. TECHNOLOGY REQUIREMENT (TITLE): Improved Electrical Conductivity Polymeric Materials PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Design and Devel.																			
3. Testing																			
4. Documentation																			
5.																			
APPLICATION																			
1. Design (Ph C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Documentation																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES									1			1						2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 33

1. TECHNOLOGY REQUIREMENT (TITLE): Retention of Liquid Lubricants by Passive Means Under Passive Conditions PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structures & Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Evaluation of Barrier Films and Labyrinth Seals to reduce/prevent the loss of liquid lubricants from creep/ evaporation.

4. CURRENT STATE OF ART: Art carried through earth laboratory evaluation and has been applied in isolated cases to Flight Mechanisms. Have not been able to determine value of the film/seals as actual flight results cannot be examined as flight mechanisms are not recoverable.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

The technology of retention of small quantities of a liquid lubricant "in place" during the operation of the s/c mechanism has advanced to the state that barrier films and labyrinth seals are used with full ground laboratory testing and with positive results. The films and seals must be evaluated in a long duration space flight with recoverable components in order to completely confirm the benefits of their use.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

a) In the past, Lubrication Technologists have used more than necessary quantities of lubricants to do the job. Now, the same people are using smaller quantities/just enough to do the job and we cannot afford to lose any of the lubricant. Therefore, low surface tension barrier films and labyrinth seals are used to prevent/reduce the loss of the lube by creep/evaporation. Long duration space flights are needed to confirm our decisions.

b) Long duration space flights are required to complete evaluation of the film/seals. LDEF.

c) All missions using liquid lubricants will be benefited by this evaluation. Those with moving mechanisms (failures) and sensitive instruments (degradation of output) are especially to be benefited.

d) At present, the technique is being applied to some selected flight instruments. We need recovered mechanisms to definitely prove out the use of the films/seals.

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 33

1. TECHNOLOGY REQUIREMENT(TITLE): Retention of Liquid Lubricants by Passive Means Under Passive Conditions. PAGE 2 OF ...

7. TECHNOLOGY OPTIONS:

Use best effort. Engineering Judgments to do the selection of the lubrication methods. But the two concerns would still be creep/evaporation and contamination of adjacent sensitive instruments.

8. TECHNICAL PROBLEMS:

None.

9. POTENTIAL ALTERNATIVES:

Best Engineering Judgments.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

It is now planned to use or not use the barrier films/labyrinth seals as specified by the Lubrication Technologists.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

Surface chemistry.

DEFINITION OF TECHNOLOGY REQUIREMENT — NO. 33

11. TECHNOLOGY REQUIREMENT (TITLE): Retention of Liquid Lubricants by Passive Means Under Passive Conditions. — PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Flight																			
2. Post flight analysis and documentation																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
1. Post flight anal.& documentation																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES						1			1									2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 34

1. TECHNOLOGY REQUIREMENT (TITLE): Retention of Liquid Lubricants "in Place" Under Dynamic Conditions. PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structure & Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Evaluation of barrier films/labyrinth seals to reduce/prevent the loss of liquid lubricants by creep/evaporation in the space environment in a dynamic condition.

4. CURRENT STATE OF ART: Barrier films/seals are used to date in selected cases to prevent/reduce loss of lubricant by creep/evaporation but we have not been able to fully evaluate their usefulness. HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

The technology has been carried through the earth laboratory evaluation stage and into its selected use on a few flight mechanisms. Full testing will not be completed until long duration space flight and test mechanisms are recovered and examined on earth by the Experimenter.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

a) Lubrication Technologists in the past have used more lubricant than necessary as that was the state of the art. Today, the same people are recommending the smallest quantity possible in order to do the job. As there is no excess and the operational conditions will be dynamic, we must be able to retain all of the lubricant 'in place'.

b) Long Duration Exposure Facility

c) All missions using mechanical components will benefit by these efforts as long life and non-contamination will be more assured.

d) Must be space flight proven. To date this has not been done unquestionably.

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 34

1. TECHNOLOGY REQUIREMENT(TITLE): Retention of Liquid Lubricants 'In Place' Under Dynamic Conditions. PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

Use the present methods as determined by best Engineering Judgment and try to justify mechanical failure or optical/sensor contamination on a minimum mission basis.

8. TECHNICAL PROBLEMS:

None.

9. POTENTIAL ALTERNATIVES:

Best Engineering Judgment basis or ground evaluation.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

It is now planned to use/or not use the film/seal technique as specified by the Lubrication Technologist on a best judgment basis.

EXPECTED UNPERTURBED LEVEL —

11. RELATED TECHNOLOGY REQUIREMENTS:

Surface chemistry, mechanical design.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 34

1. TECHNOLOGY REQUIREMENT (TITLE): Retention of Liquid Lubricants 'In Place' Under Dynamic Conditions. PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Flight																			
2. Post flight evaluation																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Post documentation																			

13. USAGE SCHEDULE:

																		TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES						1		1										2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 35

1. TECHNOLOGY REQUIREMENT (TITLE): Effects of Space Environment on the Properties of Specific Polymeric Materials PAGE 1 OF 3

2. TECHNOLOGY CATEGORY: Structures and Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To expose specific polymeric materials to the space environment for comparison to earth laboratory data; to expose specific polymers for a long time (3-5 years) in space.

4. CURRENT STATE OF ART: Laboratory data has been collected and compiled for use by Designers and Engineers but no space flight data is specifically known.

HAS BEEN CARRIED TO LEVEL 5

5. DESCRIPTION OF TECHNOLOGY

The technology involved is polymer chemistry and outgassing, contamination and physical properties of polymeric materials.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☒ C/D

6. RATIONALE AND ANALYSIS:

a) Need long duration exposure data to compare with out earth laboratory data.

b) Long Duration (3-5 years) Exposure Facility-LDEF

c) Improved materials selection for many missions and especially reduction/prevention of loss of sensor data quality by contamination from outgassed products.

d) 10

TO BE CARRIED TO LEVEL 10

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 35

1. TECHNOLOGY REQUIREMENT(TITLE): Effects of the Space Environment on the Properties of Specific Polymeric Materials PAGE 2 OF 3

7. TECHNOLOGY OPTIONS:

To continue to select polymeric materials for space flight using earth laboratory data only.

8. TECHNICAL PROBLEMS:

None.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

To continue to evaluate new polymeric materials and select the most promising ones for space use without data on their reaction to the actual space environment.

EXPECTED UNPERTURBED LEVEL 5

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 35

1. TECHNOLOGY REQUIREMENT (TITLE): Effects of the Space Environment on the Properties of Specific Polymeric Materials

PAGE 3 OF 3

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1.																			
2.																			
3.																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Documentation																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE				1														
NUMBER OF LAUNCHES					1		1											2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 36

1. TECHNOLOGY REQUIREMENT (TITLE): Space Repair of Polymers in Electronic Assemblies PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: Instrument Electronics

3. OBJECTIVE/ADVANCEMENT REQUIRED: The objective of this program is to develop and demonstrate the materials, methods, and equipment appropriate for the application of conformal coatings and for potting to repair electronic assemblies in the space environment.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

See Page 4.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The conformal coating and potting of electronic assemblies may be required in space as repair procedures. These will have to be performed in an environment which is not necessarily compatible with presently available materials and procedures developed for Earth operations. Gravity will not be present to assist in the filling of all the voids. Volatile components of the polymers can readily outgass and result in deleterious changes in composition and resulting properties.

TO BE CARRIED TO LEVEL 7

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 36

1. TECHNOLOGY REQUIREMENT(TITLE): Space Repair of Polymers in Electronic Assemblies PAGE 2 OF 4

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

See Page 4.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 36

1. TECHNOLOGY REQUIREMENT (TITLE): Space Repair of Polymers in Electronic Assemblies PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Material Development																			
2. Technique Develop.																			
3. Test & Evaluation																			
4.																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4. Past Flight Analysis																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE									X									
NUMBER OF LAUNCHES										1			1					2

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

Current, space-approved conformal coating and potting formulations will be subjected to long-term outgassing tests to establish the quantity of volatile components. Selected materials will be modified to reduce the amount of outgassing and evaluated in comparison with the standard formulation for processing problems and adequacy for the intended applications. Methods of vacuum degassing in a controlled manner and of packaging the degassed materials will be studied and evaluated. Compositon changes and characteristics affecting the application of the resins to typical electronic assemblies will be investigated. Techniques will be devised for applying the polymens to typical worst case hardware configurations and evaluated. Any new or modified polymers developed in this program will be tested for requisite properties, such as dielectric strength.

The repair techniques developed on Earth will be evaluated in the actual space environment on the pallet of the Spacelab during an orbital mission by Spacelab crew members in the EVA mode.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 37

1. TECHNOLOGY REQUIREMENT (TITLE): Basic Studies of the Relation between Molecular Structure and Mechanical Behavior of Polymers PAGE 1 OF 1

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To generate an understanding that will permit design of polymers for specific mechanical applications.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL __

5. DESCRIPTION OF TECHNOLOGY

Multidisciplinary studies in polymer chemistry and mechanical deformation to elucidate the relationship between the detailed molecular structure of a polymer molecule and the mechanical behavior of the polymer

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

It is now possible for polymer chemists to synthesize a series of molecules with regularly varying structures. These series can be used to make polymers whose variation in mechanical properties can be directly correlated with the molecular structures. This approach will eventually lead to guidelines for polymer synthesis for specific application as structural materials as well as for the matrix component of composites. Current research is in the beginning stages. It should be encouraged and augmented.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 38

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Studies of Polymer Matrix Composite Structure Behavior

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop fundamental understanding on the atomic level of matrix composite structure and behavior in order to provide guidance for applications and the synthesis of new materials.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Studies such as the following:

1. Study of the relation between graphite fiber morphology and the mechanical behavior of the fibers and of related composites.

2. The chemistry of polymers for composite applications.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

At present temperature limitations and environmental instabilities are problems whose elimination would increase the breadth of application of polymer matrix composites. In addition costs could be reduced without sacrifice of properties if new fiber materials were developed. The latter developments can be made more efficiently if a greater basic understanding existed of the mode of operation of the presently successful graphite fiber-the relationship between its structure, composition, manufacturing variables and mechanical properties. New polymer matrix materials will result if there is a contamination and expansion of the present research on the chemistry of polymers designed for this specific purpose.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 39

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Studies in Electrochemistry

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To obtain fundamental understanding in areas of electrochemistry and physical chemistry that pertain to the development of better batteries.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Studies such as

1. Polymeric structure for battery separators.
2. Electrochemistry of high concentration electrolyte systems.
3. Electrode reactions and electrodepositon morphology.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Electrochemical systems in the form of batteries will always be important components of space systems. Greater efficiency in terms of specific weight and long lifetime will be constant demands. Historically, battery development has occurred with a minimum of basic understanding of the details of the electrochemical processes involved. Current research has shown that substantial benefits can be reaped from basic studies of as widely varied problems as the mechanism of operation of battery separators and the morphology of zine deposition and its dependence on the charging cycle. Basic Research in the electrochemistry area should be supported at greater than the present level.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 40

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Physics and Chemistry of Organic Superconductors

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop concepts for superconductive materials for application to higher temperatures then those obtainable with metals.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Theoretical solid state studies and research in synthetic organic chemistry.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Super conductivity at temperatures even as high as room temperature give promise of untold benefits to mankind. It has been hypothesized that the mechanism of superconductivity in metals can be duplicated in organic molecules of appropriate structure. At present detailed molecular structures have been proposed and attempts are being made to synthesize them. The NASA support of this research should be augmented.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 41

1. TECHNOLOGY REQUIREMENT (TITLE): Low Thermal Expansion Composite Materials for Space Structures PAGE 1 OF 1

2. TECHNOLOGY CATEGORY: Structural and Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Reduced thermal expansion coefficient materials to improve dimensional stability of large space antennas subjected to thermal cycles.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Dimensional control of large space structures subjected to thermal cycles from varying exposure must be controlled to .1cm. Active control of stability will be used to augment the materials limit of stability.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C D

6. RATIONALE AND ANALYSIS:

Monolithic materials for dimensional stability have thermal expansion coefficient of about 1 cm/cm/$^{\circ}$K. Graphite fiber composites can achieve coefficients to about 0.1cm/cm/$^{\circ}$K. Lower thermal expansion fibers of graphite and perhaps negative expansion ceramic fibers are possible. Combinations of these fibers into a composite structural way with the proper fiber ply orientation may reduce thermal expansion control levels to coefficient value. 0.01cm/cm/$^{\circ}$K.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 42

1. TECHNOLOGY REQUIREMENT (TITLE): Standardization of Composite Materials Processing and Testing PAGE 1 OF 1

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: To reduce the rea´ and apparent scatter in properties of composite materials by review and standardization of processing, inspection and testing methods.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Considerable scatter in separate material properties results from lack of standardization of processing. Scatter in measured properties obtained for a given lot of material tested at different laboratories can be traced to variation in test techniques.

P L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C D

6. RATIONALE AND ANALYSIS:

Reduction of scatter in composite material properties would increase design allowables stress levels that would decrease structural weights. Reduced volumes of composite also would decrease the cost of the component and increase the portions of the space structure that can be considered for composite materials.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 43

1. TECHNOLOGY REQUIREMENT (TITLE): Effect of Long Duration Space Exposure on Properties of Composite Materials PAGE 1 OF 1

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Composite materials are being and will be used more extensively in space structures. Long term reliability and the effect of space environment must be determined to design for safe long duration applications.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Data will be obtained on the effects of space environmental for long times. Metal matrix and polymer matrix components will be exposed in space for times up to 10 years in a pa. ve satellite such as LDEF. Composite panels including epoxy, polyimide and aluminum matrix with a range of fiber contents from 30 to 70 volume percent, and varying fiber ply orientations will be exposed. Varyi.. thermal cycles may also be include.

Panels in the exposure facility should be removed at periodic intervals, returned to earth and evaluated. A modular exchange mechanism similar to that proposed by Goddard might be adapted to permit individual panel exchanged in orbit. The opportunity to add panels provides the option of introducing improved composites developed as part of the continuing composite development program. One input to that improvement is the data on space environmental effects.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The weight of space structures such as antennas and vehicles may be reduced by up to 50 percent by using composite materials instead of conventional materials. Further reliability requirements for space structures can be much more stringent than for earth applications. Long service life is also required. The space environment can be sufficiently antayonistic to cause degradation. Polymer matrix composites can be embrittled by radiation outgassed by the vacuum and aluminum matrix composites may be degraded by thermal cycling. Data are needed for space application of materials for the little known space environment, the need for data for composites, a newer material, is greater.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 44

1. TECHNOLOGY REQUIREMENT (TITLE): Characterization of Damage Mechanisms Associated with Failure and Degradation of Composite Materials PAGE 1 OF 4

2. TECHNOLOGY CATEGORY: (9) Structural and spacecraft mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: To identify mechanisms associated with composite material degradation as related to material configuration and dimensions, and service environment, including loading and chemical (Cont'd)

4. CURRENT STATE OF ART: Constant amplitude cyclic loading time to failure with no chemical environment input. General trends with environmental variables being identified.

HAS BEEN CARRIED TO LEVEL 1

5. DESCRIPTION OF TECHNOLOGY

It is generally accepted that the next major improvement in utilizing materials at significantly higher strength levels will be accomplished through more widespread use of advanced filamentary composite materials. Composite materials development has reached the point where reliable, predictable, reproduceable resin matrix material is available to the extent that stardardization of certain systems is near realization. Metal matrix composite material has reached the state of development where high quality Boron Aluminum and Bor-Sic Aluminum can be produced to individual specification. The major deficiency in technology development of the entire class of advanced filamentary composite materials lies in the understanding of damage mechanisms which can cause degradation of failure in service. Presently, the utilization of these materials appears vital to almost any (Cont'd)

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Laboratory test programs have progressed sufficiently to demonstrate that classical damage mechanisms of crack initiation and growth, crack stability, and environmental reaction and interaction as developed and applied to structural metals and other isotropic materials are not directly applicable to composite materials. In addition, the unique opportunity to tailor composite materials with respect to reinforcing direction will require characterization of many combinations of ply lay-ups which may result in major differences in damage modes. The process of delamination and load transfer by alternate paths needs additional experimental work in order to develop models for predicting cumulative damage and failure times. Extensive experimental programs to investigate environmental effects of temperature, moisture, radiation, erosion, gaseous reaction, and their synergism with the loading environment are required. Effects of space radiation and hard vacuum on damage produced by cyclic loading are needed in order to develop predictive performance capability for very long duration missions. Experimental programs should identify variables which have a significant effect on the damage mechanism and which should be included as inputs for developing analytical models to predict performance.

TO BE CARRIED TO LEVEL __

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 44

1. TECHNOLOGY REQUIREMENT(TITLE): Characterization of Damage Mechanisms Associated with Failure and Degradation of Composite Materials

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

Definition of environment interaction required real time testing and associated long lead time for providing structural reliability for very long life components.

9. POTENTIAL ALTERNATIVES:

None.

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS:

New composite materials development.

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 44

1. TECHNOLOGY REQUIREMENT (TITLE): Characterization of Damage Mechanisms Associated with Failure and Degradation of Composite Materials PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis and design of experiment.																			
2. Specimen preparation																			
3. Exposure and Testing																			
4. Analysis design and model.																			
5. Development of long life prediction																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
TECHNOLOGY NEED DATE																		
NUMBER OF LAUNCHES				2	2	2	2	2										

14. REFERENCES:

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 44

1. TECHNOLOGY REQUIREMENT (TITLE): Characterization of Damage Mechanisms Associated with Failure and Degradation of Composite Materials PAGE 4 OF 4

(Continuations)

3. effects and their interaction. To develop damage theory models and analytical techniques to predict materials behavior in service.

5. space mission where large, lightweight structure is required. These include large microwave reflectors, antennae, solar farms, space telescopes, and space stations.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 45

1. TECHNOLOGY REQUIREMENT (TITLE): Manufacture of Composite Materials In Space PAGE 1 OF 1

2. TECHNOLOGY CATEGORY: ____________

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop materials processes and equipment to fabricate very long structural members in space. These section structural members so produced can be assembled into light weight structures in space.

4. CURRENT STATE OF ART: ____________

HAS BEEN CARRIED TO LEVEL ___

5. DESCRIPTION OF TECHNOLOGY

Polymer matrix prepreg or aluminum ingot and form fiber spools can be transported in a much smaller volume as bulk material then an array of composite structural beams or tubes. Processing equipment and techniques suitable for space fabrication will be developed and evaluated in research on earth. These will be adaptions of existing technology modified as necessary. It may be found that improved composite materials are required at a future date; consequently, fabrication techniques should be evaluated in a space environment to increase confidence.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Antennae structures from 100 to 1000 meters have been indicated as possible for space application. Large structures of this size have been indicated by the structures group to be larger than optimum for earth manufacture. Assembly of earth fabricated structural elements is possible; however it may be advantageous to orbit raw materials and fabricate the structural elements in space. Partly to reduce the volume orbited but also to make long thin elements not easily produced with earth gravitational effects.

TO BE CARRIED TO LEVEL ___

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 46

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Materials and Processes for Assembly of Structures in Space

2. TECHNOLOGY CATEGORY: Structural and Spacecraft/Mechanical

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop joining procedures, (i.e. welding, brazing, bonding) for assembling modular composite structural elements (i.e. tubes and beams) to make light weight structures such as antennas as large as 1000 meters.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Joining methods will be adapted for space use, demonstrated in tests on earth and at a later date considered for space demonstration.

P/L REQUIREMENTS BASED ON: ☒ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

It has been proposed that structures above a certain size, for example antennas larger than 30m in diameter, should be assembled in space from structured elements brought up to space. Structures larger than 100 meters may benefit from assembly in space of structured elements manufactured in space from bulk raw materials.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 47

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Basic Solid State Physics of Metal Matrix Composites

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop fundamental understanding of the strucuture of the composite at the atomic level in order to provide guidance for their development manufacture and application.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Studies such as the following will be made:

1. Internal friction and elasticity of boron fibers
2. Internal stress distributions in fibers produced by chemical vapor deposition and the effects of stress distribution on mechanical properties.
3. Physics and chemistry of fiber-matrix interfaces.
4. Thermal fatigue in composite structures.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The development of metal matrix composites has been based either on existing technology or by the pursuit of fruitful approaches developed by cut and try methods. The state of the art is now at a point where the development of basic understanding can provide the most profitable approach to improved materials. Examples are: (a) a better understanding of the nature of the fiber-matrix bond and its contribution to tensile strength and impact strength, (b) an understanding of the stress distribution in the fiber and its effect on the mechanical behavior, (c) the role of the unusual anelasticity of boron on its mechanical properties and on fabrication of the composite. New basic problems will arise as the spectrum of uses widens.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 48

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Studies of Creep and Fracture Mechanisms in Composites

2. TECHNOLOGY CATEGORY: Basic Materials Research

3. OBJECTIVE/ADVANCEMENT REQUIRED: To develop an understanding of the mechanisms of energy absorption and fracture in composite structures in order to guide development and application.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Studies in fractography, dislocation interactions and multiplication, theory of cracking, fiber-matrix interactions during straining, internal friction studies.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The deformation and fracture of a composite material are processes of a higher order of complexity than those manifested in homogeneous materials. It is necessary to increase the understanding of the modes by which load is transformed from matrix to the fiber, the behavior of the fiber-matrix bond during straining the effect of surface flaws on crack initiation, the role played by the grown-in stress distribution in the fiber, and other questions whose elucidation will lead to better materials. Basic research in these areas is minimal or non-existent at present.

TO BE CARRIED TO LEVEL

SPACE MATERIALS TECHNOLOGY REQUIREMENTS
Opportunity Driven

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 49

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 1

Development of Directionally Solidified Eutectic Compounds in Space

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop new materials with a continuous fibrous phase, that is, fewer defects in the eutectic structure, by solidification in low gravity.

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Directionally solidified eutectics currently in development on earth for increasing uniaxial strength in aircraft turbine blades and fasteners are limited. The rod-like reinforcing phase is not continuous but has defects due to disturbances from convection while solidifying.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Metallic superalloy (e.g., nickel-columbium) eutectic compounds can be used for high strength jet engine turbine blades or optical slits or glassy compounds can be used for laser windows. The reduced convection of the molten material, and the quiescent conditions of spacecraft in orbit are considered to be beneficial to the achievement of this objective. It is believed that a more nearly perfect structure could be produced in low gravity. Economic studies indicate that this work could save vast amounts of fuel and money in the aircraft industry.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 50

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 2

Containerless Casting and Shaping of Reactive Metals in Space

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop electromagnetic, electro-hydrodynamic and acoustic levitation and control equipment, aided by low gravity, to contain and to shape reactive metals and ceramics without molds, crucibles or other containers.

4. CURRENT STATE OF ART: Metals and ceramics react with the mold, crucible or shaping container. Silicon single crystals are sliced from a rod like (Cont'd)

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Some prototype of apparata for levitating molten material have been built, and much additional effort is required for instrumentation of the initial demonstration flight equipment including storage, levitating, melting, cooling, capturing and final storage for return of a simple sphere. Once the material is handled successfully, laboratory studies of the differences in chemical purity and metallurgical micro-structure are required. More advanced instrumentation for shaping molten material other than spheres during levitation will be required in development and in flight experiment demonstrations. Only then can metallurgists have the tools to do research and try new solidification techniques using zero gravity not only for eliminating containers but for controlling structure.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Many special metal requirements are not being filled currently because metals and ceramics react with the mold, crucible or shaping container. The production of ribbon "extruded" silicon single crystal in which wafer could be cut out like cookies rather than sliced from a rod like salami would be a major advancement to electronics if the flat surface were undisturbed. Tungsten x-ray targets and filaments need higher purity for longer life and safety as do thermionic devices for energy production and control. Most of these are small and of high unit value. Control and handling of the product by levitation in low gravity with electro-magnetic or acoustic fields would eliminate chemical reactions with containers.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 50

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 2 OF 2

Containerless Casting and Shaping of Reactive Metals in Space

(Continued)

4. salami and the flat surface is disturbed. Tungsten x-ray targets and filaments need higher purity for longer life and safety as do thermionic devices for energy production and control.

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 51

1. TECHNOLOGY REQUIREMENT (TITLE): Fabrication, Assembly and Joining of Materials for Large Space Structures PAGE 1 OF 1

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: Develop processes for producing and joining light-weight structural materials (e.g., rods and sheets of metal foams) in space for large space structures.

4. CURRENT STATE OF ART: None.

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

Materials and processes research in foamed metal, design of a modular space assembly system, design of tooling to produce the desired panels in space and planning and implementing a space experiment to prove the concept. An initial space experiment is needed to produce the foamed metal in the low gravity and vacuum conditions of space.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

The large space structure will be needed to provide for an antenna for transmission of solar electric power to earth, a mirror for direction of concentrated solar radiation to earth-based power generators, either voltaic or thermal, and for a space station for habitation of space construction and maintenance workers. Thus, a space structure is needed in the near future to support the energy needs of earth. A space-base for other needs (e.g., manufacturing and research in low gravity) will be needed later. The foamed-metal in-space technique will allow materials of construction to be transported easily in the Space Shuttle in compact form and deployed in space as a large, light-weight structure. Otherwise, many trips of the Space Shuttle will be required if light-weight, pre-formed but bulkly modules are produced on earth for erection into a space structure.

TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 52

1. TECHNOLOGY REQUIREMENT (TITLE): PAGE 1 OF 4

Space Processing of Ceramics and Glass

2. TECHNOLOGY CATEGORY:

3. OBJECTIVE/ADVANCEMENT REQUIRED: The objective of this program is to develop experiments utilizing the space environment to gain information and understanding of some of the basic phenomena and behavior associated with the (Cont'd)

4. CURRENT STATE OF ART:

HAS BEEN CARRIED TO LEVEL

5. DESCRIPTION OF TECHNOLOGY

See Page 4.

P/L REQUIREMENTS BASED ON: ☐ PRE-A, ☐ A, ☐ B, ☐ C/D

6. RATIONALE AND ANALYSIS:

Ceramics and glasses have important applications both in space missions and on Earth. Ceramics exhibit high-temperature strength and inertness to certain environments and are critical to the performance of advanced nuclear and solar power systems. Special glass compositions possess characteristics critical to certain optical and laser applications. Development of new ceramics and glasses with enhanced performance and the improvement of present compositions depend upon gains in the following characteristics:

- Purity and homogeneity of ceramics and glasses
- Grain size of ceramics
- Freedom from crystallization in glasses

The space environment provides the opportunity to produce materials without a container because of the absence of gravity. Containerless processing and melting avoids the introduction of contaminants into the material from the container. Further, absence of a container allows solidification of molten material without providing nucleation sites from contact with container walls. Certain complex glass compositions are especially prone to deleterious crystallization of this type. Likewise, grain size control in those ceramics produced by the melting process would be more readily (Cont'd P.4) TO BE CARRIED TO LEVEL

DEFINITION OF TECHNOLOGY REQUIREMENT NO. 52

1. TECHNOLOGY REQUIREMENT(TITLE): PAGE 2 OF 4

Space Processing of Ceramics and Glass

7. TECHNOLOGY OPTIONS:

8. TECHNICAL PROBLEMS:

9. POTENTIAL ALTERNATIVES:

10. PLANNED PROGRAMS OR UNPERTURBED TECHNOLOGY ADVANCEMENT:

See Page 4.

EXPECTED UNPERTURBED LEVEL ___

11. RELATED TECHNOLOGY REQUIREMENTS·

DEFINITION OF TECHNOLOGY REQUIREMENT	NO. 52

1. TECHNOLOGY REQUIREMENT (TITLE): Space Processing of Ceramics and Class

PAGE 3 OF 4

12. TECHNOLOGY REQUIREMENTS SCHEDULE:

CALENDAR YEAR

SCHEDULE ITEM	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91		
TECHNOLOGY																			
1. Analysis																			
2. Ground-bases exp.																			
3. Space exp.																			
4. Test and Evaluation																			
5.																			
APPLICATION																			
1. Design (Ph. C)																			
2. Devl/Fab (Ph. D)																			
3. Operations																			
4.																			

13. USAGE SCHEDULE:

																	TOTAL
TECHNOLOGY NEED DATE																	
NUMBER OF LAUNCHES																	

14. REFERENCES:

(a) OA Input on Space Processing for 1975 OAST Summer Workshop.

15. LEVEL OF STATE OF ART

1. BASIC PHENOMENA OBSERVED AND REPORTED.
2. THEORY FORMULATED TO DESCRIBE PHENOMENA.
3. THEORY TESTED BY PHYSICAL EXPERIMENT OR MATHEMATICAL MODEL.
4. PERTINENT FUNCTION OR CHARACTERISTIC DEMONSTRATED, E.G., MATERIAL, COMPONENT, ETC.
5. COMPONENT OR BREADBOARD TESTED IN RELEVANT ENVIRONMENT IN THE LABORATORY.
6. MODEL TESTED IN AIRCRAFT ENVIRONMENT.
7. MODEL TESTED IN SPACE ENVIRONMENT.
8. NEW CAPABILITY DERIVED FROM A MUCH LESSER OPERATIONAL MODEL.
9. RELIABILITY UPGRADING OF AN OPERATIONAL MODEL.
10. LIFETIME EXTENSION OF AN OPERATIONAL MODEL.

1. TECHNOLOGY REQUIREMENT (TITLE): Space Processing of Ceramics and Glass

Present space processing programs involving ceramics and glasses have not addressed certain areas which have important implications to industry. As examples of these areas, two have been selected for discussion here. These are (1) the formation and control of bubbles in glass, and (2) the behavior of fine powders during compaction.

Bubble behavior during glass processing is of major significance in the production of containers because of the effect that bubbles have on the strength and failure characteristics of containers. This problem has plagued the glass industry for years and is of major financial significance because of the large tonnage involved. Bubble formation and behavior in molten glass in the Earth environment involves the interplay of the weak forces of surface tension and gravity. Space offers a new avenue of research towards the solution of this problem since it provides a means of studying bubbles in glass free from the influence of gravity. Experiments in the Spacelab will be designed involving the melting and processing of glass so that bubble formation and behavior can be observed and recorded. The effects of various additions to the glass will be studied and of variations in processing parameters.

The majority of ceramic products are produced by the compaction of fine powders followed by firing at high temperatures. The properties of the products depends to a great extent upon the effects of the processing parameters on the microstructure of the ceramic. Such factors as powder size, shape, and surface charge as well as compaction pressure and time have important effects. A clearer understanding of powder behavior during compaction and sintering would be useful in the development of new or improved ceramics either by space processing or terrestrial manufacturing. It is expected that the weightlessness afforded by space would provide the opportunity to acquire this understanding. Carefully designed experiments will be conducted in the Spacelab to study systematically the various parameters involved in powder compaction and processing without the effect of gravity. Powder size and distribution, particle shape, surface charge, pressure, time and temperature will be studied.

(Continuations)

3. processing of ceramics and glass. From the information gained, the development of new and improved ceramics and glasses either by space or terrestrial processing, as applicable, would be pursued.

4. involved to provide a basis for solving problems to improve terrestrial manufacturing processes. Another class of experiments in space will be designed to solve other problems by the development of processing methods for the production of improved materials in space.

CANDIDATE FLIGHT EXPERIMENTS

FUTURE PAYLOAD TECHNOLOGY NO. 5a

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. PREP DATE REV DATE LTR

CATEGORY

2. TITLE Refractory Metal Heat Pipes

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Determine the effects of long term exposure to space environment and the expected gaseous contamination on the operational capability of refractory alloy/liquid alkali metal heat pipes. It is anticipated that contamination may degrade the mechanical properties of the refractory alloy and increase the corrosion rate of the refractory alloy by the liquid metal working fluid.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980

PAYLOAD DEVELOPMENT LEAD TIME 2 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS

TECHNICAL BENEFITS Knowledge of the extent and effects of contamination from the relatively poor vacuum of near space can allow improvement of heat pipes and shielding mechanisms and subsequent reliability improvement in the systems(s) of which the heat pipes are a part (probable power systems).

POTENTIAL COST BENEFITS

ESTIMATED COST SAVINGS $

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS

REQUIRED SUPPORTING TECHNOLOGIES

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR-1) 7/75

 PRECEDING PAGE BLANK NOT FILMED

TITLE Refractory Metal Heat Pipes

NO. 5a
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8 SPACE TEST OPTION TEST ARTICLE: System should contain power source for maintaining on T-111/Li and one W/Li heat pipe each at 1800, 2300, and 2800°F.

TEST DESCRIPTION: ALT. (max/min) 150 / 300 km, INCL. ______ deg, TIME 4000+ hr

BENEFIT OF SPACE TEST: Confirm prior ground tests on the usability of heat pipes in near space.

EQUIPMENT: WEIGHT ______ kg, SIZE ____ X ____ X ____ m, POWER ______ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☒

TEST CONFIDENCE 95%

9. GROUND TEST OPTION TEST ARTICLE: Heat Pipes of Ta T-111/Li

TEST DESCRIPTION/REQUIREMENTS: Hold heat pipes at high temperatures (1800 to 2800°F) for long times in simulated space environment.

SPECIAL GROUND FACILITIES: Ultra-high vacuum test chambers with controlled leak of gases found in near space.

EXISTING: YES ☒ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE 60%

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM | COST IMPACT | PROBABILITY

COST RISK $ ______

F1 (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 5b
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY ______

2. TITLE Refractory Metal Contamination

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Near space is expected to be sufficiently contaminating to refractory metals, particularly columbuim and tantalum, as to significantly degrade their strength properties during long time service. Neither the extent of contamination nor the extent of degradation of mechanical properties are now known.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980
PAYLOAD DEVELOPMENT LEAD TIME 2 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS Knowledge of space contamination effects on the mechanical properties of refractory metals is required to allow proper design and protection (if necessary) of refractory metal components of power systems, etc..

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Refractory Metal Contamination NO. 5b

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Sheet and/or wire of candidate refractory alloys.

TEST DESCRIPTION: ALT. (max/min) 150 / 300 km, INCL. ____ deg, TIME 4000+ hr

Resistively heat specimens to 1800-2800 F° in space environment. Return to Earth for measurement of residual mechanical properties.

BENEFIT OF SPACE TEST: Confirm prior ground tests on space contamination effects on mechanical properties of refractory alloys.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☒

TEST CONFIDENCE 95%

9. GROUND TEST OPTION TEST ARTICLE: Mechanical property test specimens of refractory alloys.

TEST DESCRIPTION/REQUIREMENTS: Conduct long-term creep tests in simulated space environment. Also conduct creep and other evaluations after long-term exposure to simulated space environment.

SPECIAL GROUND FACILITIES: High vacuum creep and exposure systems with controlled leaks of space gases to simulate space environment.

EXISTING: YES ☒ NO ☐

GROUND TEST LIMITATIONS: ____

TEST CONFIDENCE 60%

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FTTDR 2/7/75

FUTURE PAYLOAD TECHNOLOGY — NO. 7

TESTING AND DEVELOPMENT REQUIREMENT — PAGE 1

1. REF. NO. Tech. Reqmt. PREP DATE 8/11/75 REV DATE ______ LTR ____

CATEGORY Large, controllable, light weight structures, very long life components/systems

2. TITLE Light Metal Alloys - Long Time, Low Earth Orbit Exposure on Mechanical Stability

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
6	6	10

Provide long exposure baseline mechanical property data for very thin gage light metal alloys of beryllium and beryllium - aluminum alloys to: Provide design constraints imposed by space environment for thin gage alloys. Provide input data for development of very long time behavior prediction capability.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1979

PAYLOAD DEVELOPMENT LEAD TIME 1 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS (1) Improved structural reliability of very long life structural systems/components (2) Consideration of residual mechanical property allowables in very long life design.

POTENTIAL COST BENEFITS Cost benefits must be weighed on the basis of increased probability of mission success.

ESTIMATED COST SAVINGS $ Med (long range)

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES (1) Fabrication and processing of thin walled structural elements.

7. REFERENCE DOCUMENTS/COMMENTS A forecast of space Technology 1980-2000, final draft Outlook for Space.

FT (TDR-1) 7/75

TITLE Light metal alloys - Long time, low earth orbit exposure on mechanical stability NO. 7 PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Thin gage structural element test specimens

TEST DESCRIPTION: ALT. (max/min) 500 / 200 km, INCL. any deg, TIME 5 hr

Expose elemental specimens to space environment and return for residual property determination environment and return for residual property determination.

BENEFIT OF SPACE TEST: Access to actual radiation, micro-meteorites, and space vacuum environment.

EQUIPMENT: WEIGHT 50 kg, SIZE .5 X .5 X .3 m, POWER 0 kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE 0.9

9. GROUND TEST OPTION TEST ARTICLE: Thin gage structural element test specimens

TEST DESCRIPTION/REQUIREMENTS: Expose specimens to high intensity UV and simulated micrometeoroid environments and measure residual property values.

SPECIAL GROUND FACILITIES: UV source, high velocity particle accelerators

EXISTING: YES [X] NO ☐

GROUND TEST LIMITATIONS: Lack of accurate environmental modeling

TEST CONFIDENCE 0.7

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 78	79	80	81	82	83	COST ($)	GROUND TEST OPTION 78	79	80	81	82	83	COST ($)
1. ANALYSIS		.02						.02	.02						.02
2. DESIGN		.05						.05	.05						.05
3. MFG & C/O			.2					.2		.2					.2
4. TEST & EVAL				.1	.1	.1	.1	.5			.02	.02	.02		.06
TECH NEED DATE															
		GRAND TOTAL						.77M	GRAND TOTAL						M

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

F1 (1DR ?) 7-75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 9a
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY Structures and Spacecraft/Mechanical

2. TITLE Processing and Use of Chemically-Active Metals in Space and Planetary Environments.

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Provide alloy theory for the use of chemically-active metals as primary alloy systems or as alloy additions to obtain unique properties which have not been contempted through the use of our earth bound technology. Such chemically active metals include sodium, potassium, and lithium.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS Our present materials technology has grown from our need to use materials in the specific chemical environment of earth. It seems unreasonable to expect such technology to produce optimum materials for use in other chemical environments such as found in space or on other planets. Many alloy systems which have proved to be poor performers on earth or which would never be considered for development on earth may perform well when exposed only to the specific environments encountered in space. Unique properties never before contemplated may be possible.

POTENTIAL COST BENEFITS Potentially unlimited. ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Processing and Use of Chemically-Active Metals in Space and Planetary Environments.

NO. 9a

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Active element alloy formation, manufacture, pro[illegible]g and evaluation in the space environment.

TEST DESCRIPTION: ALT. (max/min) ______ / ______ [illegible] ______ deg, TIME ______ hr

BENEFIT OF SPACE TEST. Material evaluation of specific alloy compositions designed for space-related environments without exposure to the environment.

EQUIPMENT: WEIGHT ______ kg, SIZE ______ X ______ X ______ m, POWER ______ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING. YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	SPACE TEST OPTION							GROUND TEST OPTION						
CY							COST ($)							COST ($)
1. ANALYSIS														
2. DESIGN														
3. MFG & C/O														
4. TEST & EVAL														
TECH NEED DATE														
	GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

[illegible]

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 9b
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY Structures and Spacecraft/Mechanical

2. TITLE Solid-Solid Metal Embrittlement in the Space Environment.

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

The theoretical extension of the theory of liquid metal embrittlement to solid-solid metal embrittlement or vapor solid metal embrittlement.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS A more complete understanding of environmental embrittlement allowing a more accurate prediction of the life of a metal structure exposed for long duration in the space environment. Solid metal embrittlement and/or vapor metal embrittlement of a metallic structure in space presents a potential problem area. In the vacuum of space many metals may lose their protective oxide coatings for a number of reasons allowing intimate contact with other metal structures or intimate contact with other metal structures or intimate exposure to other metal vapors which may be potentially degrading. Such contact may severely influence the predicted life of the metal structure.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES Understanding of the potential degradation of metal alloys by chemical environments.

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR 1) 7 75

TITLE Solid-Solid Metal Embrittlement in the Space Environment NO. 9b

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION

TEST ARTICLE: Long-term exposure of "clean" metal surfaces to other "clean" metal surfaces or "vapors" of other metals as a measure of long-term degradation of structural life.

TEST DESCRIPTION: ALT. (max/min) ______ / ______ km, INCL. ______ deg, TIME ______ hr

BENEFIT OF SPACE TEST: Maintainance of clean surfaces for long duration and the potential creation of high partial pressure metal vapors without a significant level of contamination.

EQUIPMENT: WEIGHT ______ kg, SIZE ______ X ______ X ______ m, POWER ______ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION

TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

F 1 (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 10
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY ______

2. TITLE NDT/NDE Earth and Space

3. TECHNOLOGY ADVANCEMENT REQUIRED
To advance the tecnnology of non-destructive methods for the detection and evaluation of macroscopic flaws in materials. Such that the techniques could be directly applied in space.

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS Inspection of erected space structures will have to be performed and techniques and procedures for doing this will have to be established.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE NDT/NDE Earth and Space

NO. 10
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: ____________

TEST DESCRIPTION: ALT. (max/min) ____/____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Performance of actual tests to gain confidence in procedures and equipment.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____/____

SPECIAL GROUND FACILITIES: Testing procedures for specific joint geometries, etc., will first be established by ground testing. EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____________

TEST DESCRIPTION/REQUIREMENTS: ____________

SPECIAL GROUND FACILITIES: ____________ EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ____________

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

GT (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 11
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY Structural and Spacecraft/Mechanical

2. TITLE Influence of Long-Term Space Exposure on Localized Plasticity in Metals.

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

More complete understanding of the influence of localized plasticity on flaw growth and strain energy release rates in metallic structures. A more complete understanding of how long-term exposure to high vacuum environments can influence both the character and ease of dislocation motion in metals and alloys.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS The long-term exposure of metal structures may greatly influence the ease of local plasticity. Such an influence may significantly change flaw growth rates thus significantly modifying the applicable elastic-plastic failure criteria for a structure to be used in the environment of space.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES Theoretical developments in inelastic fracture mechanics.

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Influence of Long-Term Space Exposure on Localized Plasticity in Metals. NO. 11

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Long-term exposure of various concentrations of flawed metal alloys together with a measure of flaw growth and energy release ratio.

TEST DESCRIPTION: ALT. (max/min) ______ / ______ km, INCL. ______ deg, TIME ______ hr

BENEFIT OF SPACE TEST: Maintenance of a very high vacuum for long durations at various levels of contamination.

EQUIPMENT: WEIGHT ______ kg, SIZE ______ X ______ X ______ m, POWER ______

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

F1 (1DR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY — NO. 12

TESTING AND DEVELOPMENT REQUIREMENT — PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______
CATEGORY ______

2. TITLE Solar Cell Solder Connections With Extended Life During Thermal Cycling In Orbit

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Develop an improved joint-solder combination for silicon solar cells to eliminate embrittlement by inter-metallic compound formation and, thereby, withstand thermal cycling in orbit for more than 60,000 cycles (10 years). Currently, lead-tin solder reacts with silver and titanium barrier and contact layers causing embrittlement and mechanical breakage of individual joints resulting in reduced power output with time in orbit.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980
PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1980

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS Solar cell arrays operating in earth orbit go through a large thermal gradient as much as 120°C, from sun to earth shadow. Most of the effects of the thermal gradient can be accounted for in designs (e.g. thermal expansion) but embrittlement of the solder joint to the contact layer on the cell cannot. Hard inter-metallic compounds are formed by diffusion which become brittle and cause some individual contacts to break with a concomitant loss in [redacted] power output. Heretofore, large solar arrays (Skylab, HEAO, etc.) have been overdesigned in expectation of reduced output with time. Longer life and increased power requirements for energy programs in space or on earth will preclude such a cavalier treatment of the problem. This can be solved by careful attention to the metallurgical bond in the joint and barrier layer.

ESTIMATED COST SAVINGS $ 20,000,000.00

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Solar Cell Solder Connections With Extended Life During Thermal Cycling in Orbit

NO. 12

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Solar Array

TEST DESCRIPTION: ALT. (max/min) 240 / 180 km, INCL. any deg, TIME 3yrs. ~~XX~~

BENEFIT OF SPACE TEST: Synergistic combination of all environmental parameters.

EQUIPMENT: WEIGHT 200 kg, SIZE 2 X 2 X 0.02 m, POWER None kW

POINTING Solar Rector STABILITY +1° DATA

ORIENTATION CREW: NO. OPERATIONS/DURATION /

SPECIAL GROUND FACILITIES:

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE

9. GROUND TEST OPTION TEST ARTICLE:

TEST DESCRIPTION/REQUIREMENTS:

SPECIAL GROUND FACILITIES:

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS:

TEST CONFIDENCE

10. SCHEDULE & COST

TASK / CY	SPACE TEST OPTION 77	78	79	80			COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS	▬						100k							
2. DESIGN		▬					150k							
3. MFG & C/O			▬				500k							
4. TEST & EVAL				▬			200k							
TECH NEED DATE														
GRAND TOTAL							950k	GRAND TOTAL						

11. VALUE OF SPACE TEST $ (SUM OF PROGRAM COSTS $)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $

F 1 (TDR 2) 7-75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 13
PAGE 1

1. REF. NO. ____ PREP DATE ____ REV DATE ____ LTR ____
CATEGORY ____

2. TITLE Joining Metals in Space

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

To easily and reliably produce strong metallurgical bonds for the space assembly of metallic structures by utilizing cold resistance, and explosive welding techniques. These techniques would tend to be particularly suited to the "clean" space environment.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ____
PAYLOAD DEVELOPMENT LEAD TIME ____ YEARS. TECHNOLOGY NEED DATE ____

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ____

TECHNICAL BENEFITS The placement of very large structures in space, e.g., antennae, solar cell arrays,etc., necessitates their fabrication "in-situ". Thus, modular subsystems or individual components must be joined in the space environment.

POTENTIAL COST BENEFITS ____

ESTIMATED COST SAVINGS $ ____

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ____

REQUIRED SUPPORTING TECHNOLOGIES ____

7. REFERENCE DOCUMENTS/COMMENTS ____

FT (TDR 1) 7 75

TITLE Joining Metals in Space

NO. 13

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Actual practice of performing the appropriate joining operations.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: High vacuum fabrication facility for performing collateral work on earth. EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FI (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 19
PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Basic Materials Research

2. TITLE Solid State Diffusion Studies

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

To obtain diffusion data for systems requiring very high temperatures and containerless conditions for the purpose of accumulation of data required for applications (ex. compatability) and for increased accuracy of information on high temperature materials.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS (1) Would eliminate the need for inaccurate extrapolation of long time, low temperature experiments and (2) would make data available for the investigation of possible changes in diffusion mechanism at high temperatures.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Solid State Diffusion Studies NO. 19

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Diffusion specimens exposed to vacuum and controlled high temperature (1000^{o} C and higher) -- levitated to eliminate need for container material for specimens.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr
Samples exposed to above conditions for hours to days. Returned to earth for sectioning and analysis.

BENEFIT OF SPACE TEST: Elimination of container contamination and possibility of running tests to high temperatures for shorter times.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: The experiments described above cannot be performed on the ground.

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

ELGDR 2/7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 21
PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Basic Materials Research

2. TITLE Phase Diagram Studies at Low Pressure and Zero g.

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Determination of phase diagram details at low pressures for metal systems to be used in space manufacturing and in ground based vacuum melting. Need is to better define conditions which might lead to gas bubble formation and inhomogenieties.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS Definition of conditions for improved metal products cast in vacuum and by space manufacturing techniques.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR 1) 7 75

TITLE Phase Diagram Studies at Low Pressure and Zero g. NO. 21

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Specimens of desired composition exposed to various conditions of temperature and time.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

Specimens will be heated to controlled temperatures for short times (hours) under zero g and returned to ground for further treatment.

BENEFIT OF SPACE TEST: Zero g conditions eliminate pressures generated within the sample by gravitation.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: Gravitational effects on pressure within sample destroy equilibrium conditions and invalidate the data.

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FT (TDR 2) 7 75

FUTURE PAYLOAD TECHNOLOGY NO. 22

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ____

CATEGORY Basic Materials Research

2. TITLE High Temperature Vaporization Studies of Corrosive Molten Salts

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Vaporization rates and related thermodynamic data are needed for high temperature conditions that are unattainable on the ground because of the lack of non-reactive container material. The data are for various applications, one being the elucidation of the hot corrosion phenomenon that is a serious problem in aircraft turbines, ground based power plants and marine turbines.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______

PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS The data obtained will impact a wide variety of R & D areas, one of which is hot corrosion interpretation and minimization.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE High Temperature Vaporiztion Studies of Corrosive Molten Salts — NO. 22 — PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION — TEST ARTICLE: Material sample levitated in molten condition and associated equipment including temperature control and mass spectrometer.

TEST DESCRIPTION: ALT. (max/min) ______ / ______ km, INCL. ______ deg, TIME ______ hr

Heat sample and measure its change in mass with time and detect with mass spectrometer the molecular species that are vaporized.

BENEFIT OF SPACE TEST: Can be done without the container contamination that nullifies ground based measurements.

EQUIPMENT: WEIGHT ______ kg, SIZE ______ X ______ X ______ m, POWER ______ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION — TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: The experiments cannot be performed on the ground because the container materials required on the ground contaminate the specimens.

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM — COST IMPACT — PROBABILITY

COST RISK $ ______

LEDR 2? 7 75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 28
PAGE 1

1. REF. NO. ______ PREP DATE 8/11/75 REV DATE ______ LTR ______
CATEGORY Structural & Spacecraft/Mechanical

2. TITLE Adhesive Bonding of Large Erectable Structures in Space

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

The objective of this program is to develop, evaluate and demonstrate the materials, techniques, processes, and equipment required for assembly by adhesive bonding of the constituent components of large, space-erectable structures. The requirement for long life in the space environment will necessitate the development and evaluation of new adhesive formulations. Actual space demonstration of the developed bonding techniques and equipment will be conducted in orbit outboard the pallet of the Spacelab by experimenters equipped with space suits.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS The advantages offered by adhesive joining over other joining methods are, (1) light weight, (2) dimensional stability, (3) compatibility with lightweight non-metallic and metallic structural elements, (4) ease of fabrication and (5) minimal tooling and equipment.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES Structures

7. REFERENCE DOCUMENTS/COMMENTS SPART Study Report; OSS, OA User Inputs to 1975 OAST Summer Workshop Overview Report

FT (TDR-1) 7/75

TITLE Adhesive Bonding of Large Erectable Structures

NO. 28

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Adhesively Bonded Joints

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: (1) Life test of adhesive joints in space (2) Development and demonstration of bonding techniques

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ____

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK		SPACE TEST OPTION							GROUND TEST OPTION						
	CY	76	77	78	79	80	81	COST ($)	76	77	78	79	80	81	COST ($)
1. ANALYSIS									.05						.05
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL				.05	.2	.3	.2	.75	.05	.1	.1	.1	.2	.2	.75
TECH NEED DATE															
		GRAND TOTAL						.75	GRAND TOTAL						.80

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FT (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY NO. 29

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Structure & Spacecraft/Mechanical

2. TITLE Long Life Polymeric Protective Coatings for Space Applications

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
2	5	10

Polymeric protective coatings for solar cells, electronic circuit boards, etc. with long life under actual space conditions are needed in order to assure us of the operational lifetimes designed into the orbiting device. The technology of polymeric coatings will be advanced by this effort especially for coatings (solar cells, thermal) that are directly exposed to the Space environment.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1982
PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1979

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2

TECHNICAL BENEFITS By using improved protective coatings (better resistance to degradation by the Space environment) the life and efficiency of Solar cells, thermal coatings, circuit boards, etc., will be increased significantly.

POTENTIAL COST BENEFITS estimated to be great - 100M

ESTIMATED COST SAVINGS $?

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Formulation and synthesis of the proper polymer and its evaluations. The space evaluation of the final product is extremely important to assure us about earth testing.

REQUIRED SUPPORTING TECHNOLOGIES Analytical instrumentation, i.e., IR Spectroscopy, etc., in chemical labs as well as mechanical listing.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR-1) 7/75

TITLE Long Life Polymeric Protective Coatings for Space Applications

NO. 29
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE:

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Confirmation of earth laboratory data & especially long life space test under actual condition

EQUIPMENT: WEIGHT 50 kg, SIZE 0.030 X 0.086 X 0.127 m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: clean room

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE:

TEST DESCRIPTION/REQUIREMENTS: Actual space environmental condition-Vacuum, thermal, Zero g, radiation (U.V. & particles), and meteoric bombardment

SPECIAL GROUND FACILITIES: all of above

EXISTING: YES [ ] NO [ ]

GROUND TEST LIMITATIONS: Simultaneous long time exposure to the above test requirements.

TEST CONFIDENCE 0.90

10. SCHEDULE & COST

TASK	CY	78	79	80	81	82	83	COST ($) (SPACE TEST OPTION)							COST ($) (GROUND TEST OPTION)
1. ANALYSIS			.03												
2. DESIGN				.04											
3. MFG & C/O					.05										
4. TEST & EVAL					.06	.05									
TECH NEED DATE															
GRAND TOTAL								0.24M	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

LL (TDR 21 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 30
PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Structure and Spacecraft/Mechanical

2. TITLE Long Life Adhesives for Space Applications

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	5	10

The Chemistry of polymers (adhesives) must be investigated and developed to the point that the adhesives unprotected from the space environment (external to the S/C) must withstand the severe conditions of thermal extremes, vacuum, zero-g, radiation and meteorite bombardment without degradation of these intended properties.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1982
PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1980

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2
TECHNICAL BENEFITS Better adhesives for such items as solar cells and thermal tapes must be developed for our long life orbiting devices and Lunar and Mars, Landers, etc., in order to assure their success.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS Formulating and synthesis of the polymer adhesive and long time testing in a simulated space environment.

REQUIRED SUPPORTING TECHNOLOGIES Chemistry, space simulations testing.

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Long Life Adhesives for Space Applications NO. 30

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Long life polymeric adhesives

TEST DESCRIPTION: ALT. (max/min) ______ / ______ km, INCL. ______ deg, TIME ______ hr

BENEFIT OF SPACE TEST: Actual testing in the space environment and post examination of specimens

EQUIPMENT: WEIGHT 30 kg, SIZE 0.003 X 0.86 X 1.27 m, POWER 0 kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: Clean room

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE 0.85

9. GROUND TEST OPTION TEST ARTICLE: Long life polymeric adhesives

TEST DESCRIPTION/REQUIREMENTS: Simulated space environment long term (1-3 years)

SPECIAL GROUND FACILITIES: ______

EXISTING: YES [ ] NO [X]

GROUND TEST LIMITATIONS: Actual space environment including Zero-g and full radiation for long term (1-3 years)

TEST CONFIDENCE 0.3

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 77	78	79	80	82	83	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS		.03	.02												
2. DESIGN			.03												
3. MFG & C/O				.02	.03										
4. TEST & EVAL					.05		.06								
TECH NEED DATE															
		GRAND TOTAL						0.24M	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

F T (T DR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 31
PAGE 1

1. REF. NO. ____ PREP DATE 8/9/75 REV DATE ____ LTR ____
CATEGORY Structures and Spacecraft/Mechanics

2. TITLE High Temperature High Thermal Conductivity Polymers for Space Application

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
3	5	10

Advancement in high temperature (>300 degree range) high thermal conductivity polymer chemistry will be the product of this effort. Polymer chemistry must formulate and synthesize chemical structures to achieve these goals.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1982
PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1980

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2
TECHNICAL BENEFITS Mechanisms and devices can be operated at high temperatures and operate more efficiently.

POTENTIAL COST BENEFITS Much

ESTIMATED COST SAVINGS $ ____

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS Polymer chemistry has to investigate the problem by structural chain changes and modifications, or by the filling of polymers with various thermal conducting substances.

REQUIRED SUPPORTING TECHNOLOGIES Polymer chemistry and space simulation testing.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR-1) 7/75

TITLE High Temperature High Thermal Conductivity Polymers for Space Application | NO. 31 | PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Polymers-High Temperature-High Thermal conductivity

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Confirm laboratory results and to improve knowledge of polymer selection

EQUIPMENT: WEIGHT 50 kg, SIZE 0.03 X 0.86 X 1.27 m, POWER -0- kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: Clean room

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE 0.90

9. GROUND TEST OPTION TEST ARTICLE: Polymers - High Temperature High Thermal conductivity.

TEST DESCRIPTION/REQUIREMENTS: Actual space environment for long term exposure.

SPECIAL GROUND FACILITIES: ____

EXISTING: YES [ ] NO [X]

GROUND TEST LIMITATIONS: Above long term facility.

TEST CONFIDENCE 0.3

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 78	79	80	81	82	83	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS		0.03	0.02												
2. DESIGN			0.03												
3. MFG & C/O				0.03											
4. TEST & EVAL					0.04		0.04								
TECH NEED DATE															
		GRAND TOTAL						0.19M	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

F1 (TDR 2) 7 75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 32
PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Structural & Spacecraft/Mechanical

2. TITLE Improved Electrical Conductivity of Polymers for Space Application.

3. TECHNOLOGY ADVANCEMENT REQUIRED

Advancement in polymer chemistry to increase the electrical conductivity of the polymer by molecular structure change or addition of electrical conducting substances.

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
2	3	10

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1983
PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1983

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2

TECHNICAL BENEFITS Improved electrical conductivity of external coating will allow better control of space charges and in grounding of boxes and other applications where electrical conduction is necessary.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS Polymer Chemistry may not be able to rearrange the molecular structure in order to achieve the goal, but progress has been made in using specific electrical conducting fillers.

REQUIRED SUPPORTING TECHNOLOGIES Chemistry, laboratory, testing.

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR 1) 7/75

TITLE Improved Electrical Conductivity of Polymers for Space Application. NO. 32

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Polymeric materials

TEST DESCRIPTION: ALT. (max/min) ______ / ______ km, INCL. ______ deg, TIME ______ hr

BENEFIT OF SPACE TEST: To determine if the coating will perform predicted in the space environment.

EQUIPMENT: WEIGHT 50 kg, SIZE 0.03 X 0.86 X 1.27 m, POWER ______ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: Clean room

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE 0.90

9. GROUND TEST OPTION TEST ARTICLE: Polymeric materials

TEST DESCRIPTION/REQUIREMENTS: Space environment including electrical - static charges.

SPECIAL GROUND FACILITIES: Space simulated environment including electrical charging.

EXISTING: YES [ ] NO [X]

GROUND TEST LIMITATIONS: above

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK		SPACE TEST OPTION							GROUND TEST OPTION						
	CY	79	80	81	82	83	84'	COST ($)							COST ($)
1. ANALYSIS			0.04												
2. DESIGN			0.02												
3. MFG & C/O				0.03	0.03										
4. TEST & EVAL					0.04		0.04								
TECH NEED DATE															
		GRAND TOTAL						0.2M	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

FT (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 33
PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Structural and Spacecraft/Mechanical

2. TITLE Retention of Liquid Lubricants by Passive Means in the Space Environment Under Passive Conditions

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
5	5	10

To better understand the use of low surface tension barrier films and labyrnith seals in the prevention/reduction of the loss of lubricants by creep and evaporation. This experiment will show the importance of the films and seals by being able to examine a controlled experiment before and after flight.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980
PAYLOAD DEVELOPMENT LEAD TIME 1.5 YEARS. TECHNOLOGY NEED DATE 1976

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2
TECHNICAL BENEFITS Retention of the liquid lubricant "In-Place" is of great importance in order that the mechanism does not fail mechanically and adjacent sensitive instruments are not contaminated.

POTENTIAL COST BENEFITS Increased lifetime of S/C instruments is immeasurable as some instruments have failed after 1-3 mo. and some up to 3 years. 7-10 year lifetimes are now planned. Mechanisms will be able to operate until power fails
ESTIMATED COST SAVINGS $ 100M

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS At this time, no technical problems are foreseen.

REQUIRED SUPPORTING TECHNOLOGIES Optical microscopy, chemical analysis, failure analysis.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR 1) 7/75

TITLE Retention of Liquid Lubricants by Passive Means in the Space Environment Under Passive Conditions

NO. 33

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE:

TEST DESCRIPTION: ALT (max/min) / km, INCL. deg, TIME hr

BENEFIT OF SPACE TEST: To evaluate the effect of Zero g on the creep of liquids and the use of the barrier film to reduce the creep.

EQUIPMENT: WEIGHT 50 kg, SIZE .03 X .40 X .45 m, POWER 0 kW

POINTING STABILITY DATA

ORIENTATION CREW: NO. OPERATIONS/DURATION /

SPECIAL GROUND FACILITIES:

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE 0.90

9. GROUND TEST OPTION TEST ARTICLE:

TEST DESCRIPTION/REQUIREMENTS: Space environment including Zero g.

SPECIAL GROUND FACILITIES: Zero g capability

EXISTING: YES [ ] NO [X]

GROUND TEST LIMITATIONS: Cannot get Zero g conditions on ground

TEST CONFIDENCE 0.90

10. SCHEDULE & COST

TASK	SPACE TEST OPTION CY 76	77	78	79	80	81	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS		.02												
2. DESIGN			.03											
3. MFG & C/O				.10										
4. TEST & EVAL					.05									
TECH NEED DATE														
	GRAND TOTAL						0.2M	GRAND TOTAL						

11. VALUE OF SPACE TEST $ 0.2M (SUM OF PROGRAM COSTS $)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $

LLTDR 2/7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 34
PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Structures & Spacecraft/Mechanical

2. TITLE Retention of Liquid Lubricants "in Place" Under Dynamic Conditions Using Barrier Films and Labyrnith Seals

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
5	5	10

Lubrication of Mechanical components has advanced to the state where-in a Minimum quantity of lubricant is used, this quantity cannot be lost to space or contaminate sensitive devices. This experiment is set up to better confirm the use of barrier films and labyrnith seals to prevent the loss of the liquid lubricants by creep/evaporation under conditions of rotary motion and Zero g.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980
PAYLOAD DEVELOPMENT LEAD TIME 1.5 YEARS. TECHNOLOGY NEED DATE 1976

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2
TECHNICAL BENEFITS Retention of the lubricant "In Place" under dynamics conditions is a must in order to prevent mechanical failure and contamination of sensitive instruments. Very small quantities of lubricants are now being employed and they cannot be lost by creep/evaporation.

POTENTIAL COST BENEFITS The operational lifetime of S/C instruments will be more assured if the barrier films and labyrnith seals do function as expected.

ESTIMATED COST SAVINGS $ 100M

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS No technical problems exist at this time in the use of these films and seals

REQUIRED SUPPORTING TECHNOLOGIES Optical microscopy, chemical analysis, failure analysis.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR 1) 7/75

TITLE Retention of Liquid Lubricants "In Place" Under Dynamic Conditions Using Barrier Films and Labyrnith Seals

NO. 34

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION

TEST ARTICLE:

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: To evaluate the use of the barrier film and labyrnith seals in the Zero g field on creep/evaporations of liquid Lubricants.

EQUIPMENT: WEIGHT 50 kg, SIZE .03 X .40 X .45 m, POWER 0.005 kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: Clean Room

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE ____

9. GROUND TEST OPTION

TEST ARTICLE:

TEST DESCRIPTION/REQUIREMENTS: Space environment including Zero g

SPECIAL GROUND FACILITIES: Zero g capability

EXISTING: YES [ ] NO [ ]

GROUND TEST LIMITATIONS: Zero g capability

TEST CONFIDENCE 0.90

10. SCHEDULE & COST

TASK	CY	76	77	78	79	80	81	COST ($) (Space)							COST ($) (Ground)
1. ANALYSIS			.02												
2. DESIGN				.03											
3. MFG & C/O					.10										
4. TEST & EVAL						.05									
TECH NEED DATE															
GRAND TOTAL								0.2M	GRAND TOTAL						

11. VALUE OF SPACE TEST $ 0.2M

(SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM

COST IMPACT

PROBABILITY

COST RISK $

FT (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 35
PAGE 1

1. REF. NO. ______ PREP DATE 8/9/75 REV DATE ______ LTR ______
CATEGORY Structure and Spacecraft/Mechanical

2. TITLE Effects of the Space Environment on the Properties of Specific Polymers.

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED
5	5	10

Knowledge of the combined effects of the space environment on the properties of specific/most used polymeric materials is needed in order to confirm our selection and earth laboratory data. This experiment will be evaluated after space flight, 1-3 years, to determine if our selections of polymers is correct; and to show which polymers is correct and which polymers should be improved. Polymer chemistry will be advanced.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980
PAYLOAD DEVELOPMENT LEAD TIME 1 YEARS. TECHNOLOGY NEED DATE 1978

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 2
TECHNICAL BENEFITS Knowledge confirming our past selection of polymeric materials are planned. This long duration Space exposure will allow us to actually measure some properties of polymeric materials after exposure.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS If the polymers do degrade badly in Space, then improved polymers are needed. If they do not degrade significantly, only longer life (7-10 years) polymer chemistry must be looked at.

REQUIRED SUPPORTING TECHNOLOGIES Polymer Chemistry.

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Effects of the Space Environment on the Properties of Specific Polymers. NO. 35

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Polymeric Materials

TEST DESCRIPTION: ALT. (max/min) ____/____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Assurance of our proper selection of the various polymeric materials and space applications.

EQUIPMENT: WEIGHT 60 kg, SIZE 0.03 X 0.86 Y 1.27 m, POWER 0 kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW· NO. ____ OPERATIONS/DURATION ____/____

SPECIAL GROUND FACILITIES: Clean room

EXISTING: YES [X] NO [ ]

TEST CONFIDENCE .90

9. GROUND TEST OPTION TEST ARTICLE: Polymeric Materials

TEST DESCRIPTION/REQUIREMENTS: Long term (1-3 years) exposure to the actual space environment.

SPECIAL GROUND FACILITIES: Actual space environment exposure facilities - long term exposure.

EXISTING: YES [ ] NO [XX]

GROUND TEST LIMITATIONS: Actual space environment exposure facility for long term duration.

TEST CONFIDENCE 0.3

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 76	77	78	79	80	81	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS			0.03				.03								
2. DESIGN				0.03											
3. MFG & C/O				0.02	0.03										
4. TEST & EVAL					0.05		0.05								
TECH NEED DATE															
		GRAND TOTAL						0.24M	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

LT (TDR 2) 7 75

FUTURE PAYLOAD TECHNOLOGY NO. 36

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE 8/11/75 REV DATE ______ LTR ____

CATEGORY Instrument Electronis

2. TITLE Space Repair of Polymers in Electronic Assemblies

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

The objective of this program is to develop and demonstrate the materials, methods, and equipment appropriate for the application of conformal coatings and for potting to repair electronic assemblies in the space environment.

These repairs will have to be performed in an environment which is not necessarily compatible with presently available materials and procedures developed for Earth operations. Gravity will not be present to assist in the filling of all the voids. Volatile components of the polymers can readily outgas and result in deleterious changes in composition and resulting properties.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______

PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS ______

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Space Repair of Polymers in Electronic Assemblies NO. 36

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION

TEST ARTICLE:

TEST DESCRIPTION: ALT. (max/min) / km, INCL. deg, TIME hr

BENEFIT OF SPACE TEST:

EQUIPMENT: WEIGHT kg, SIZE X X m, POWER kW

POINTING STABILITY DATA

ORIENTATION CREW: NO. OPERATIONS/DURATION /

SPECIAL GROUND FACILITIES:

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE

9. GROUND TEST OPTION

TEST ARTICLE:

TEST DESCRIPTION/REQUIREMENTS:

SPECIAL GROUND FACILITIES:

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS:

TEST CONFIDENCE

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 76	77	78	79	80	81	COST ($)	GROUND TEST OPTION 76	77	78	79	80	81	COST ($)
1. ANALYSIS									.02	.02					.04
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL						.1	.1	.2	.03	.03	.01		.02	.02	.11
TECH NEED DATE															
		GRAND TOTAL						.2	GRAND TOTAL						.15

11. VALUE OF SPACE TEST $ (SUM OF PROGRAM COSTS $)

12. DOMINANT RISK/TECH PROBLEM

COST IMPACT PROBABILITY

COST RISK $

FT (TDR 2) 7-75

FUTURE PAYLOAD TECHNOLOGY NO. 43

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______

CATEGORY ______

2. TITLE Long Term Space Exposure of Composite Materials

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Long term reliability of present and advanced composite materials exposed to the space environment will be established in order to permit the safe design of composite structures for long duration space application. The influence of such effects as UV radiation and long term outgasing of polymeric matrix composites and the thermal degradation of metallic matrix composites must be established.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______

PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______

TECHNICAL BENEFITS The better capability of accurate and reliable life prediction of metal and polymeric matrix, present and advanced composite materials for long duration space exposure.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES Composite materials development.

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR 1) 7/75

TITLE Long Term Space Exposure of Composite Materials NO. 43
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Variable exposure of UV and thermal radiation for long duration such as on a passive satellite.

TEST DESCRIPTION: ALT. (max/min) ____ / ____ km, INCL. ____ deg, TIME ____ hr

BENEFIT OF SPACE TEST: Realistic exposure to service environment.

EQUIPMENT: WEIGHT ____ kg, SIZE ____ X ____ X ____ m, POWER ____ kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ____

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION						COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS															
2. DESIGN															
3. MFG & C/O															
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL							GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

I I (TDR 2 7 75

FUTURE PAYLOAD TECHNOLOGY — NO. 44

TESTING AND DEVELOPMENT REQUIREMENT — PAGE 1

1. REF. NO. ____ PREP DATE 8/11/75 REV DATE ____ LTR ____

CATEGORY Large controllable, light weight structures, very long life components/systems

2. TITLE Effects of Space Environmental Effects on Fatigue and Fracture of Advanced Filamentary Composite Structural Materials

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Determine effects of long time two/high earth orbit space exposure fatigue and fracture of composite materials. Develop inputs for development of life prediction models for very long life space applications involving light weight structures.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1979

PAYLOAD DEVELOPMENT LEAD TIME 1 YEARS. TECHNOLOGY NEED DATE 1985

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 5-10

TECHNICAL BENEFITS (1) Potentially large weight savings in large erectable structures.

(2) Greater structural reliability in very long life applications.

POTENTIAL COST BENEFITS ____

ESTIMATED COST SAVINGS $ high

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ____

REQUIRED SUPPORTING TECHNOLOGIES Composite materials development

7. REFERENCE DOCUMENTS/COMMENTS ____

FT (TDR-1) 7/75

TITLE Effects of Space Environmental Effects on Fatigue and Fracture of Advanced Filamentary Composite Structural Materials NO. 44 PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Composite material elemental fracture and fatigue specimens

TEST DESCRIPTION: ALT. (max/min) 200 / 500 km, INCL. any deg, TIME 5 yr. xx
Expose elemental specimens to low/high earth orbit space environment without load under constant load and under cyclic load and subsequent ground interpretation and analysis.

BENEFIT OF SPACE TEST: Realistic service environment exposure

EQUIPMENT: WEIGHT 250 kg, SIZE 2 X 3 X .3 m, POWER 0-1 kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE .5

9. GROUND TEST OPTION TEST ARTICLE: Composite material elemental fracture and fatigue test specimens

TEST DESCRIPTION/REQUIREMENTS: Expose specimens to combinations of hard vacuum, high intensity UV radiation, and simulated micrometeorid impact and determine effects on residual properties.

SPECIAL GROUND FACILITIES: High vacuum chambers, High intensity UV radiation sources, high velocity particle accelerators

EXISTING: YES ☒ NO ☐

GROUND TEST LIMITATIONS: Realistic environment interaction unachievable

TEST CONFIDENCE .9

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 78	79	80	81	82	83	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS		.035						.035	.035						.035
2. DESIGN		.07						.07	.07						.07
3. MFG & C/O		.2						.2	.2						.2
4. TEST & EVAL			.1	.1	.1	.1	.1	.5		.03	.03				.06
TECH NEED DATE															
		GRAND TOTAL						.8M	GRAND TOTAL						.35 M

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

FF (1DR 2) 7-75

FUTURE PAYLOAD TECHNOLOGY NO. 49

TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ____ PREP DATE ____ REV DATE ____ LTR ____

CATEGORY ____

2. TITLE Development of Directionally Solidified Eutectic Compounds in Space

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Develop new materials with a continuous fibrous phase, that is, fewer defects in the eutectic structure, by solidification in low gravity. These include metallic superalloy (e.g. nickel-columbrium) eutectic compounds for high strength jet engine turbine blades or optical salts or glassy compounds for laser windows. The reduced convection of the molten material, and the quiescient conditions of spacecraft in orbit are considered to be beneficial to the achievement of this objective.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980

PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1980

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 9

TECHNICAL BENEFITS Directionally solidified eutectics currently in development on earth for increasing uniaxial strength in aircraft turbine blades and fasteners are limited. The rod-like reinforcing phase is not continuous but has defects due to disturbances from convection while solidifying. It is believed that a more nearly perfect structure could be produced in low gravity.

POTENTIAL COST BENEFITS Economic studies indicate that this work could save vast amounts of fuel and money in the aircraft industry.

ESTIMATED COST SAVINGS $ ~~more than~~ 100,000,000.00

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ____

REQUIRED SUPPORTING TECHNOLOGIES ____

7. REFERENCE DOCUMENTS/COMMENTS ____

FT (TDR 1) 7/75

TITLE Development of Directionally Solidified Eutectic Compounds In Space

NO. 49

PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Materials Processing Spacelab

TEST DESCRIPTION: ALT. (max/min) 240 / 180 km, INCL. any deg, TIME 200 hr

BENEFIT OF SPACE TEST: Must provide low gravity

EQUIPMENT: WEIGHT 150 kg, SIZE 0.6 X 0.4 X 0.2 m, POWER 20 kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK	CY	SPACE TEST OPTION 76	77	78-9	80	81	82	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS								200k							
2. DESIGN								400k							
3. MFG & C/O								1400k							
4. TEST & EVAL								500k							
TECH NEED DATE															
		GRAND TOTAL						2500k	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

GDR 2/7/75

FUTURE PAYLOAD TECHNOLOGY — NO. 50

TESTING AND DEVELOPMENT REQUIREMENT — PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ______

CATEGORY ______

2. TITLE Containerless Casting and Shaping of Reactive Metals in Space

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Develop electromagnetic, electro-hydro-dynamic and acoustic levitation and control equipment, aided by low gravity, to contain and to shape reactive metals and ceramics without molds, crucibles or other containers.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1980

PAYLOAD DEVELOPMENT LEAD TIME 5 YEARS. TECHNOLOGY NEED DATE 1984

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 3

TECHNICAL BENEFITS Many special metal requirements are not being filled currently because metals and ceramics react with the mold, crucible or shaping container. The production of ribbon "extruded" silicon single crystal in which the wafer could be cut out like cookies rather than sliced from a rod like salami would be a major advancement to electronics if the flat surface were undisturbed. Tungsten x-ray targets and filaments need higher purity for longer life and safety as do thermoionic devices for energy production and control.

POTENTIAL COST BENEFITS - Reduces a large amount of scrap and surface etching in semi-conductors. ESTIMATED COST SAVINGS $50,000,000.00

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES ______

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR 1) 7/75

TITLE Containerless Casting and Shaping of Reactive Metals in Space | NO. 50 | PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: Materials Test Spacelab

TEST DESCRIPTION: ALT. (max/min) 240 / 180 km, INCL. any deg, TIME any hr

BENEFIT OF SPACE TEST: Provide low gravity environment

EQUIPMENT: WEIGHT 100 kg, SIZE 1 X 1 X ½ m, POWER 10 kW

POINTING ____ STABILITY ____ DATA ____

ORIENTATION ____ CREW: NO. ____ OPERATIONS/DURATION ____ / ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ____

9. GROUND TEST OPTION TEST ARTICLE: ____

TEST DESCRIPTION/REQUIREMENTS: ____

SPECIAL GROUND FACILITIES: ____

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ____

TEST CONFIDENCE ____

10. SCHEDULE & COST

TASK	SPACE TEST OPTION CY 77	78	79	80	81	82	COST ($)	GROUND TEST OPTION						COST ($)
1. ANALYSIS	—	—					300k							
2. DESIGN		—	—				400k							
3. MFG & C/O			—	—			1800k							
4. TEST & EVAL				—	—	—	1000k							
TECH NEED DATE														
GRAND TOTAL							3500k	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ____ (SUM OF PROGRAM COSTS $ ____)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ____

FUTURE PAYLOAD TECHNOLOGY
TESTING AND DEVELOPMENT REQUIREMENT

NO. 51
PAGE 1

1. REF. NO. ______ PREP DATE ______ REV DATE ______ LTR ____
CATEGORY ______

2. TITLE Fabrication, Assembly and Joining of Materials for Large Space Structures

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

Develop processes for producing and joining light-weight structural materials (e.g. rods and sheets of metal forms) in space for large space structures. This includes selection of materials, melting, controlled gas-bubble blowing and extrusion facilities, selection of joining methods and equipment and designs of an integrated system to provide materials of construction in-situ.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE 1979
PAYLOAD DEVELOPMENT LEAD TIME 3 YEARS. TECHNOLOGY NEED DATE 1981

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS 3

TECHNICAL BENEFITS The large space structure will be needed to provide for an antenna for transmission of solar electric power to earth, a mirror for direction of concentrated solar radiation to earth-based power generators, either voltaic or thermal, and for a space station for habitation of space construction and maintenance workers. Thus, a space structure is needed in the near future to support energy needs to earth. A space-base for other needs (e.g. manufacturing and research in low gravity) will be needed later.

POTENTIAL COST BENEFITS: The foamed metal in-space technology will allow materials of construction to be transported easily in the Space Shuttle in compact form. Otherwise, many trips would be required.

ESTIMATED COST SAVINGS $20,000,000/structure

6. RISK IN TECHNOLOGY ADVANCEMENT

TECHNICAL PROBLEMS
RISK IN TECHNOLOGY ADVANCEMENT
Technical Problems

REQUIRED SUPPORTING TECHNOLOGIES Materials and processes research in foamed metal, design of a modular space assembly system, design of tooling to produce the desired panels in space and planning and implementing a space experiment to prove the concept. An initial space experiment is needed to produce the foamed metal in the low gravity and vacuum conditions of space.

7. REFERENCE DOCUMENTS/COMMENTS

FT (TDR 1) 7 75

TITLE Fabrication, Assembly and Joining of Materials for Large Space Structures

NO. 51
PAGE 2

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION

TEST ARTICLE: Simple Foamed metal experiment to prove process and obtain samples for testing on earth.

TEST DESCRIPTION: ALT. (max/min) 240 / 180 km, INCL. any deg, TIME any hr

BENEFIT OF SPACE TEST: Needed to obtain zero gravity

EQUIPMENT: WEIGHT 150 kg, SIZE 1 X 0.5 X 0.2 m, POWER 10 kW

POINTING None STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION

TEST ARTICLE: ______

TEST DESCRIPTION/REQUIREMENTS: ______

SPECIAL GROUND FACILITIES: ______

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ______

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK		SPACE TEST OPTION							GROUND TEST OPTION						
	CY	76	77	78	79	80	81	COST ($)							COST ($)
1. ANALYSIS								300k							
2. DESIGN								300k							
3. MFG & C/O								600k							
4. TEST & EVAL								600k							
TECH NEED DATE															
		GRAND TOTAL						1800k	GRAND TOTAL						

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

F1 (TDR 2) 7/75

FUTURE PAYLOAD TECHNOLOGY NO. 52
TESTING AND DEVELOPMENT REQUIREMENT PAGE 1

1. REF. NO. ______ PREP DATE 8/11/75 REV DATE ______ LTR ______
CATEGORY ______

2. TITLE Space Processing of Ceramics and Glass

3. TECHNOLOGY ADVANCEMENT REQUIRED

LEVEL OF STATE OF ART		
CURRENT	UNPERTURBED	REQUIRED

The objective of this program is to develop experiments utilizing the space environment to gain information and understanding of some of the basic phenomena and behavior associated with the processing of ceramics and glass. From the information gained, the development of new and improved ceramics and glasses either by space or terrestrial processing, as applicable, would be pursued.

4. SCHEDULE REQUIREMENTS FIRST PAYLOAD FLIGHT DATE ______
PAYLOAD DEVELOPMENT LEAD TIME ______ YEARS. TECHNOLOGY NEED DATE ______

5. BENEFIT OF ADVANCEMENT NUMBER OF PAYLOADS ______
TECHNICAL BENEFITS New or improved ceramics with enhanced properties will be developed for space and Earth applications.

POTENTIAL COST BENEFITS ______

ESTIMATED COST SAVINGS $ ______

6. RISK IN TECHNOLOGY ADVANCEMENT
TECHNICAL PROBLEMS ______

REQUIRED SUPPORTING TECHNOLOGIES (a) OA Input on Space Processing for 1975 OAST Summer Workshop Overview Report

7. REFERENCE DOCUMENTS/COMMENTS ______

FT (TDR-1) 7/75

TITLE Space Processing of Ceramics and Glass NO. 52

COMPARISON OF SPACE & GROUND TEST OPTIONS

8. SPACE TEST OPTION TEST ARTICLE: ____________________

TEST DESCRIPTION : ALT. (max/min) ______ / ______ km, INCL. ______ deg, TIME ______ hr

BENEFIT OF SPACE TEST: ____________________

EQUIPMENT: WEIGHT ______ kg, SIZE ______ X ______ X ______ m, POWER ______ kW

POINTING ______ STABILITY ______ DATA ______

ORIENTATION ______ CREW: NO. ______ OPERATIONS/DURATION ______ / ______

SPECIAL GROUND FACILITIES: ____________________

EXISTING: YES ☐ NO ☐

TEST CONFIDENCE ______

9. GROUND TEST OPTION TEST ARTICLE: ____________________

TEST DESCRIPTION/REQUIREMENTS: ____________________

SPECIAL GROUND FACILITIES: ____________________

EXISTING: YES ☐ NO ☐

GROUND TEST LIMITATIONS: ____________________

TEST CONFIDENCE ______

10. SCHEDULE & COST

TASK		SPACE TEST OPTION							GROUND TEST OPTION						
	CY	76	77	78	79	80	81	COST ($)	76	77	78	79	80	81	COST ($)
1. ANALYSIS									0.050	.050	0.05				0.15
2. DESIGN															
3. MFG & C/O						0.3	0.5	0.8		0.1	0.1	0.1	0.1	0.1	0.5
4. TEST & EVAL															
TECH NEED DATE															
		GRAND TOTAL						0.8	GRAND TOTAL						0.65

11. VALUE OF SPACE TEST $ ______ (SUM OF PROGRAM COSTS $ ______)

12. DOMINANT RISK/TECH PROBLEM COST IMPACT PROBABILITY

COST RISK $ ______

FT (TDR 2) 7/75